

Corrosion

IN THIS ISSUE:

FOCUS on INDUSTRIAL COATINGS

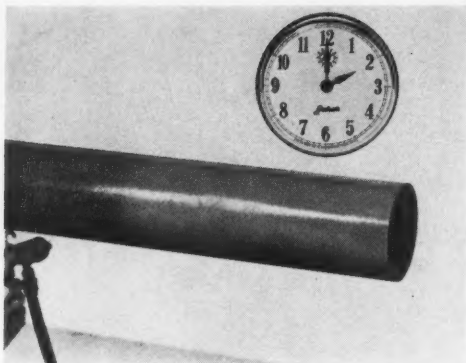
Baked Phenolic Coatings in Process Industries	9
Epoxies Give Good Service in Well Casing Coating Test	14
Special Coupon Shapes Used in Testing Liner Coatings	16
Surface Reconditioning of the Key West Water Pipeline	20
Effect of Application Variables on Maintenance Coating Performance	22
Responsibilities of High Performance Maintenance Coating Manufacturer	26
Epoxy Coatings' Susceptibility to Fresh Water Immersion	28

Management's Stake in Corrosion Control	30
Corrosion of Steel Oil Field Tubing in Hydrochloric Acid	86
Cathodic Polarization of Steel in Sea Water	100
Specifications for Industrial Maintenance Painting	121
Protective Coatings in Petroleum Production	129

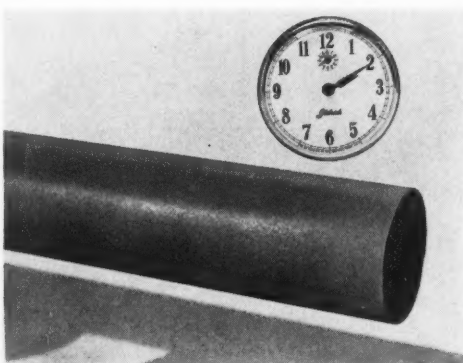
ALSO: Complete Program for Appalachian
Underground Corrosion Course, Page 60.

Complete Contents on Pages 4 and 5





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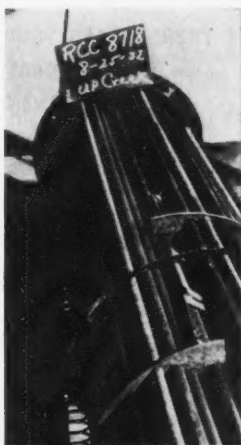
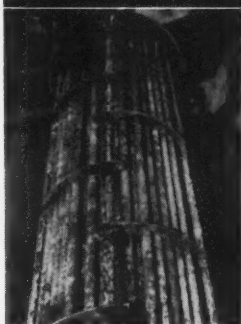
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This Month in Corrosion Control . . .

HANDLING CRUDE OILS with hydrogen sulfide concentrations on the order of 130 lb. per thousand barrels puts the best materials to a severe test. In one refinery desulfurization unit where heavy corrosion damage was being suffered, as reported on Page 79, it was learned that 9 percent chromium content tubes would have an estimated service life of five years.

FUEL ELEMENT LIFE up to 10,000 hours is expected to be obtained from a nickel-base alloy cladding selected by designers of a gas-cooled nuclear reactor. As explained in a report beginning on Page 81, the material had to satisfactorily resist corrosion by high temperature nitrogen gas and retain mechanical strength to handle 300 psi.

CORROSION RATE versus time for J-55 oil well tubing in contact with inhibited 15 percent hydrochloric acids at several temperatures is given in an article beginning on Page 86. Attack on the tubing in contact with trapped acid was found not to be sufficient to cause failure in most instances.

LABORATORY SIMULATION of corrosive plant conditions, especially effective in establishing precise temperature versus corrosion parameters of an alloy in a specific environment, are reported beginning on Page 93. An all-glass, pressurized, heat transferring test unit is described which was used by the author to produce data under five different heat conditions. Examples of data obtained with the test unit are given.

STEEL EXPOSED to produced fluid from West Texas oil fields is studied in an article beginning on Page 100. The effects of temperature changes and varying amounts of organic acids is reported. Carbon dioxide and hydrogen sulfide definitely depolarize steel in a salt water system.

HOW HOT HYDROGEN SULFIDE streams affect welded stainless steels in a commercial desulfurizer and additional information on heat treatment and composition is covered beginning on Page 105. In the thermally stabilized condition, manganese substituted stainless steels were slightly better than conventional nickel stainless steels.

SCALE DEPOSITED on heat-transfer surfaces in oil producing equipment is estimated to cost between \$1.5 and \$2 million dollars annually in the United States alone. Beginning on Page 110 is a discussion of this scale problem in which a laboratory test for effectiveness of inhibitor additives is described. Results of tests on many commonly used inhibitive mixtures are reported.

SINGLE IRON CRYSTALS which exhibit characteristic plane surfaces and cubic dimensions have been produced by a laboratory method described on Page 115. Photographs show size distribution of crystals formed and typical "whisker" growth.

Focus on INDUSTRIAL COATINGS

BAKED PHENOLIC COATINGS used to protect vessels storing organic chemicals are discussed beginning on Page 9. Experience data on surface preparation, application methods, baking cycles, and a rating against 439 chemicals are included.

OIL WELL CASINGS protected by an effective coating, require less cathodic protection. A report on an 18-month test of eleven coatings on a 2536-foot string is given beginning on Page 14.

LINER COATINGS tests are a challenge because standard coupons give data distorted by edge-effect variables. The Moebius ring is suggested as a coupon which produces more consistent data. See Page 16.

RECONDITIONING coating on the 130-mile fresh water aqueduct serving Florida south of Florida City involved application of a half-inch coating. Nearly 1000 Dresser couplings were reconditioned. Page 20.

APPLICATION VARIABLES' effect on performance of industrial coatings is surveyed beginning Page 22. Variables include spray-to-work distance, film thickness, generic types, air caps and double application.

HIGH PERFORMANCE PAINT manufacturers need to know and do a good deal to be successful. One long-time manufacturer in this field describes the manufacturer's responsibilities. Page 26.

EPOXY COATINGS submerged in fresh water may blister within a year if conditions of humidity and temperature during application are not favorable. Turn to Page 28.

PROTECTIVE COATINGS for petroleum production equipment are discussed in detail in a 16-page NACE Technical Committee report T-6E beginning on Page 129. Covered are surface preparation and treatments, application, inspection, coverage rates, reflection painting, contractor selection, typical defects, design problems and safety.

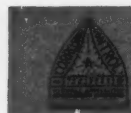
ALUMINUM EXPOSED TO HIGH PURITY WATER has second phase particles which significantly affect the corrosion pattern. Two types of second phase particles are described in experiment reported on Page 117.

SURFACE PREPARATION and material application specifications can be reduced to a manageable size through use of a coding system suggested in the NACE committee report beginning on Page 121. System notations are designed to permit the paint engineer in a chemical company to rationally specify what he wants.

ALUMINIZED STEEL WIRE is examined with respect to its resistance to corrosion in marine, severe marine, severe industrial and semi-rural atmospheres. Data are given comparing aluminum-coated and galvanized steel wire and improved properties after exposure compared to bare steel wire are reported. Turn to Page 123.

CHLORINATED POLYETHER-coated plug valves handling sulfuric acid at varying concentrations and temperatures have lasted over two years as replacements for stainless steel valves designed to last 1 1/4 years. Plastic coated valves cost one-fourth as much as the stainless valves they replaced. Turn to Page 33.

VINYL-URETHANE coatings have successfully protected crop-spraying planes from corrosion damage. The two-part coating has a pot life of about eight hours. See Page 38.



CONTENTS

This Month in Corrosion Control.....	3
Incidentally Built-In Obsolescence—An Editorial.....	7

TECHNICAL TOPICS

FOCUS ON INDUSTRIAL COATINGS	
Survey of Application Data on Baked Phenolic Coatings Used in Process Industries By L. S. VanDelinder.....	9
Epoxies Give Good Service in Well Casing Coating Test By William R. Lambert.....	14
Special Coupon Shapes Used in Testing Liner Coatings By Oliver W. Siebert.....	16
Discussion: L. W. Gleekman, Charles W. Ambler, Robert L. Collins and William A. Hess, Page 18; Replies by Oliver W. Siebert, Page 18.	
Surface Reconditioning of the Key West Water Pipeline By Kurt A. Gruber.....	20
Effect of Some Application Variables on Maintenance Coating Performance By J. R. Allen, F. W. Thompson and M. L. Monack.....	22
Discussion: Joseph J. Picarazzi, John D. Keane, Page 24; Replies by J. R. Allen, Page 24.	
Responsibilities of High Performance Maintenance Coating Manufacturer By C. G. Munger.....	26
Susceptibility of Epoxy Coatings to Damage by Fresh Water Immersion By Harold Moroson.....	28
Management's Stake in Corrosion Control By F. L. LaQue.....	30

RECORD AND REPORT

	Page		Page
Plastic Coated Valves Resist Two-Year Refinery Exposures.....	33	Periodicals	37
Italian Metallurgy Meeting.....	33	Vinyl-Urethane Coating System Used on Crop Spraying Airplane.....	38
Book News.....	34	Eleven Corrosion Papers to Be on Achema Program.....	38
Ratio Changes Made Easily on Epoxy Proportioning Unit.....	36	International Galvanizing Conference to Be June 4-9.....	38
Chemical Resistant Tubing Has Bonded Inner Plastic Lining.....	36	Plastics in Packaging.....	38
Strange Low Temperature Reaction Experienced.....	36	Titanium Used for Corrosion Resistant Aircraft Wheels.....	38
Correspondence Course Available on Corrosion.....	37	Powder Metallurgy Meeting.....	38
Australian Corrosion Group Changes Association Name.....	37	New Products.....	40
		Men in the News.....	44

Index to Advertisers.....	6
Advertised in This Issue.....	6
Corrosion Abstracts	73

TECHNICAL COMMITTEE ACTIVITIES

T-3F Changes Name to Explain Group's Complete Activities.....	47
Georgia Electrolysis Group Affiliates With NACE T-7C.....	47
Kulman Appointed Vice Chairman of Technical Practices.....	47
T-6B Establishes New Task Group on Silicones.....	47
New Committee Officers.....	47

NACE NEWS

Papers Solicited for 1962 Conference Program	49
Slides Available on 1961 Conference and Corrosion Show.....	49
Northeast Region News Boston Short Course Registration to Be \$15.....	49
Baltimore-Washington Section.....	49
Philadelphia Section.....	49
Genesee Valley Section.....	49
North Central Region Conference Program Listed.....	50
Technical Practices Committee Report Given for 1960-61.....	51
Treasurer's Report Given for 1960....	52
South Central Region News Fourth South Central Region Exhibition to Be October 24-26....	54
Houston Section Schedules Program Through January.....	54
Central Oklahoma Section.....	54
Permian Basin Section.....	54
Shreveport Section.....	54
Greater Baton Rouge Section.....	54
Treseder Is Reappointed Publications Chairman.....	56
Data Wanted on Corrosion Caused by Bird Droppings.....	56
Canadian Region News Toronto Section Completes Program Schedule for '61.....	60
Calgary Section.....	60
Montreal Section.....	60
Edmonton Section.....	60
Complete Schedule Given for June 6-8 Appalachian Short Course.....	60
McFarland, Munger and Gribble Nominated as 1962-63 Officers....	62
Only Corporate Member Directory to Be Published.....	62
Official Report of Nominating Committee	63
Mark F. Adams Appointed NACE Education Chairman.....	63
Southeast Region News Plans for Sunny Miami Conference. President Greco to Speak at Southeast Conference.....	64
Atlanta Section Program Planned Through December.....	64
Section Calendar.....	64
High School Student Wins Awards With Corrosion Display-Project....	66
Publication Committee Activities.....	66
Regional Management Committee Report Given at Buffalo.....	68
ISCC Chairman Gives Survey of Committee Activities.....	68
Overseas Correspondents.....	70
New Committee to Make Young Author Awards.....	70
National and Regional Meetings and Short Courses.....	70

CONTENTS

TECHNICAL SECTION

Page		Page
47	High Temperature Sulfur Corrosion of Intermediate Range Chromium Steels—Topic of the Month	79
47	By R. E. Hannum.....	
47	Corrosion of Nickel-Based Alloys in High Temperature Nitrogen Environments	81
47	By J. S. Brunhouse and G. W. Titus.....	
	W. V. Ward, J. E. Draley, Warren E. Berry, Page 85;	
	Replies by J. S. Brunhouse and G. W. Titus, Page 85	
	Effect of Acid Volume and Inhibitor Quantity on Corrosion of Steel Oil Field Tubing in Hydrochloric Acid	86
49	By William E. Billings and David Morris.....	
49	Discussion: L. K. Gatzke, Charles C. Nathan, Page 92;	
	Replies by William E. Billings, Page 92	
49	New Methods of Simulating Corrosive Plant Conditions in the Laboratory	93
49	By A. Orman Fisher.....	
50	Discussion: F. W. Fink, Page 99; Reply by A. Orman Fisher, Page 99	
51	Cathodic Polarization of Steel in Salt Water	100
52	By A. R. Erben.....	
	Discussion: Bryant W. Bradley, Page 104; Reply by A. R. Erben, Page 104	
54	Welded Stainless Steels for Hot Hydrogen Sulfide Service	105
54	By Frank J. Bruns.....	
54	Development of a Mineral Scale Inhibitor	110
56	By L. W. Jones.....	
56	Discussion: Ben Sloat, Glenn Ray Roberson, Ed D. Parsons, Page 114; Replies by L. W. Jones, Page 114	
60	Growth of Single Iron Crystals for Corrosion Studies—A Technical Note	115
60	By Willard F. Brickell and Edward C. Greco.....	
60	Corrosion of Aluminum Alloys in High Purity Water in the Range 150 C-340 C	117
62	By D. F. MacLennan.....	
62	Specification Format for Surface Preparation and Material Application for Industrial Maintenance Painting—A Report of NACE Technical Unit T-6D on Industrial Maintenance Painting, Prepared by Task Group T-6D-2 on Standardization of Scope of Painting Specifications. Publication 61-1.....	121
63	Laboratory and Service Evaluation of Aluminized Steel Wire	123
63	By Jane H. Rigo.....	
64	Protective Coatings in Petroleum Production—A Report of NACE Technical Unit Committee T-6E on Protective Coatings in Petroleum Production. Publication 61-2.....	129

Corrosion

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Vol. 17 May, 1961 No. 5

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ADVERTISED IN THIS ISSUE

A	Metallic 32	P
ANODES	Petroleum base 37	PIPE
Carbon..... 54	Phenolic, baked on..... 21, 43	Fittings, plastic..... 72
Graphite..... 75	Pipeline..... 2, 29	Glass fiber, epoxy..... 72
Impressed current..... Inside	Plastisol..... 21	Tapes..... 46, 48, 56
back cover	Polyurethane..... 21	
Magnesium..... 54, 65, 77	Thin film, temporary..... 39	PIPELINE
Platinum-titanium..... 57	Vinyl..... 39	Coating application
Zinc..... 67, 77	Zinc filled, inorganic..... 19, 41	services..... 21, 29, 43
	Zinc silicate, inorganic..... 27,	Dielectric unions..... 18
B	inside front cover	Fittings, plastic..... 72
Backfill, coke breeze..... 54	Coupons, testing..... 36	Spacers, insulating..... 65
		Wrapping services..... 29, 44
C	D	PLASTICS
CATHODIC PROTECTION	Dielectric unions..... 18	Cement, polyester..... 71
Anodes..... 54, 57, 67, 75	F	Fiberglass, reinforced..... 42
77, inside back cover	Fittings, plastic..... 72	Pipe glass fiber epoxy..... 72
Backfill, coke breeze..... 54	G	Tank linings..... 55
Dielectric unions..... 18	Galvanizing materials..... 77	Plating materials..... 77
Engineering	I	PROCESS EQUIPMENT
services..... 30, 44, 57, 63	INHIBITORS	Heat exchangers..... 32
Installation services..... 44, 57, 63	Acid pickling..... 58, 59	Monel..... 61
Rectifiers..... 20, 63	Oil and gas wells..... back cover	Plastic hoods, ducts, tanks..... 42
Surveys..... 30, 44	Petroleum..... 31	
Cement, chemical resistant..... 71	Producing wells..... 53	R
Chemical treatment services..... 30	Waterflood operations	Rectifiers..... 20, 63
	back cover	S
COATINGS	Insulating spacers..... 65	Salt, synthetic sea..... 50
Application services..... 21, 30, 44	INSTRUMENTS	Spacers, insulating..... 65
Chlorinated rubber..... 25	Flaw detector..... 45	T
Coal tar..... 69	Pipe finders..... 40	Tank linings..... 55
Cold set..... 6	L	TAPES
Concrete floor..... 33	LININGS	Polyethylene..... 46, 56
Crew training..... 8	Pipe, internal..... 43	Polyethylene, high density..... 48
Elastomer..... 10	Tank..... 55	Testing..... 44, 45
Epoxy..... 15, 21	N	Test supplies..... 36
Epoxy enamels..... 39	Nickel alloys..... 61	
Epoxy resin catalyzed..... 35		
Field testing..... 8		
Industrial..... 8, 11		
Inspection services..... 41		
Maintenance..... 6, 41		
Mastic..... 69		

INDEX TO ADVERTISERS

Vol. 17

May, 1961

No. 5

Alon Processing Inc..... 32	International Nickel Company, Inc. The	
Amchem Products, Inc..... 58, 59	Huntington Div..... 61	
Amercoat..... Inside Front Cover	Koppers Company, Inc.	
American Cyanamid	Tar Products Division..... 69	
Plastics and Resins Division..... 71	Lake Products Company..... 50	
Arno Adhesive Tapes, Inc..... 56	Markal Company..... 11	
Branson Instruments, Inc.	Marwais Manufacturing Division..... 65	
Ultrasonic Test Div..... 45	Napko Corporation..... 8	
Carboline Company..... 41	National Association of Corrosion	
Cathodic Protection Service..... 57	Engineers..... 51	
Consolidated Mining and Smelting	National Carbon Company	
Company of Canada Limited, The..... 67	Division of Union Carbide Corporation..... 75	
Copon Associates..... 15	Plastic Applicators, Inc..... 2	
Corrosion Engineering Directory..... 44	Polyken Sales Division	
Corrosion Rectifying Company..... 30	The Kendall Company..... 46	
Corrosion Services, Inc..... 63	Positions Wanted and Available..... 34	
Corrosion Test Supplies..... 36	Standard Pipeprotection, Inc..... 29	
Dowell..... Back Cover	Tapecoat Company, The..... 48	
du Pont de Nemours, E. I. & Co., (Inc)	Tretolite Company, Division	
Finishes Division..... 39	Petrolite Corporation..... 1	
Duriron Company, The..... Inside Back Cover	Truscon Laboratories, Division	
du Verre, Incorporated..... 42	Devoe & Reynolds Co. Inc..... 19	
Epcor Sales..... 18	Tube-Kote, Inc..... 21	
Federated Metals Division	Tubular Lining Corporation..... 43	
American Smelting & Refining Co..... 77	Universal Oil Products Company	
Fisher Research Laboratory, Inc..... 40	Products Department..... 31	
Garlock Inc..... 55	Valvoline Oil Company	
Glidden Company, The	Division of Ashland Oil & Refining	
Industrial Paint Division..... 35	Company..... 37	
Good-All Electric Manufacturing Co..... 20	Visco Products Co., Inc..... 53	
Hercules Powder Company	Wilbur & Williams Company, Inc..... 10	
Cellulose Products Department..... 25	Wisconsin Protective Coatings Co..... 6	
Humble Oil & Refining Company..... 27	Wholesale Coke Company..... 54	
	Youngstown Sheet & Tube Company	
	Fibercast Division..... 72	

Incidentally Built-In Obsolescence

MUTUAL RECRIMINATIONS between critics and supporters of American advertising have reached deafening proportions. Big guns in the advertising field have been especially aggressive in laying down a counter-barrage. There is reason to doubt some products are built with the best interests of the user in mind. The oddest circumstance is that the controversy on built-in obsolescence suddenly has reached major proportions without either side coming to grips with the real problem. In their eagerness to discredit each other, both sides tend to overlook the fundamental issues involved.

People in corrosion control are involved in this controversy to the extent that the real or alleged implications of intentional obsolescence are true or false. Our concern here is to point out facts about the possibility of extended life and service through proper consideration of corrosion factors. We are not concerned about the intentions of manufacturers with respect to their products; we are concerned about their attitudes toward corrosion control.

It seems that the problem is fundamental in the basic concept of mass production. The goal of the mass producer is to make as many units as possible at as low a cost as possible and to sell each unit at a price which will produce the largest net profit on total operations.

This price may not be the same as "the highest the traffic will bear." In following this program, the manufacturer then is subjected to one degree or another of control by the following:

1. **Marketing Experts.** Who try to estimate how many can be sold.

2. **Advertising and Sales Experts.** Who try to estimate the best means of getting recognition and organizing the best sales strategy.

Advocates of the "waste-maker" concept contend that advertising causes people to buy things they do not need and which they often would be better off without. They say marketing people get into the act by estimating how many things consumers can be persuaded to buy which are not needed.

The essential fallacies in the "waste-maker" argument can be summarized in two groups.

1. In most cases, the marketing expert acts **before** the product is produced. Successful companies have learned they cannot expect a high order of success in selling a product for which a demand does not exist **before** the product is produced and offered for sale. Demand for a product and a **need** for it are not necessarily the same.

2. Because this is true, the contention that advertising **creates** these demands does not have much weight. This is true at least for most products which have a real, practical use; it may not be true for the few that have no real value. Advertising and sales try to exploit and intensify the demand.

There is considerable difference between what a person **needs** and what he **wants**. Most of the things we have satisfy **wants**, not **needs**.

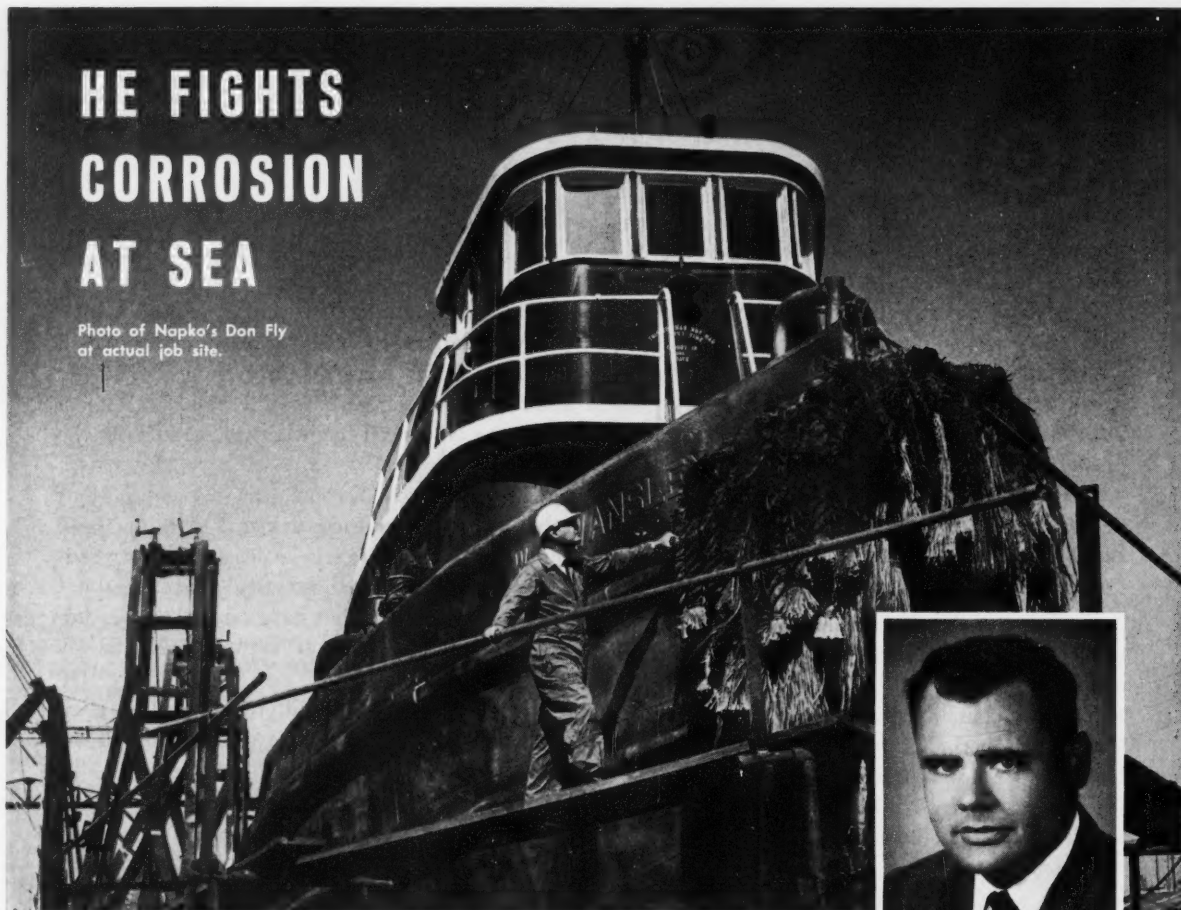
What does all this have to do with corrosion control? We believe that progress will be made in durability of products when mass producers concern themselves more about **how long** their products will last, how much freedom from avoidable breakdowns and repair costs the consumer can expect. This does not mean that the initial premise of a mass production economy is wrong. It does mean that emphasis on superficial attributes of no practical service value needs to be reduced. It does mean that manufacturers should seek advantage over their competitors by producing things that last longer and **cost less over their expected service life**. This is as true for consumer goods as it is for capital goods.

To do this, manufacturers need not abandon esthetic values, but they will need to put esthetics into proper perspective with the other values in their products. In other words, more integrity and fewer superlatives.

We do not believe many manufacturers **intend** to produce goods which have built-in obsolescence. We do believe many of them ignore the values of long service. Fortunately, in industry, the concept of long service is universal. We hope to see it equally accepted in the field of consumer products.

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Photo of Napko's Don Fly
at actual job site.



Don Fly, Industrial Sales
Houston.

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qualified sales engineer. It's that *one crucial ingredient that doesn't come in the can*. Whatever your corrosion problems, unique or commonplace, there's a Napko Industrial coating that will help solve them for you. Won't you call your nearest Napko Sales office for your next project?

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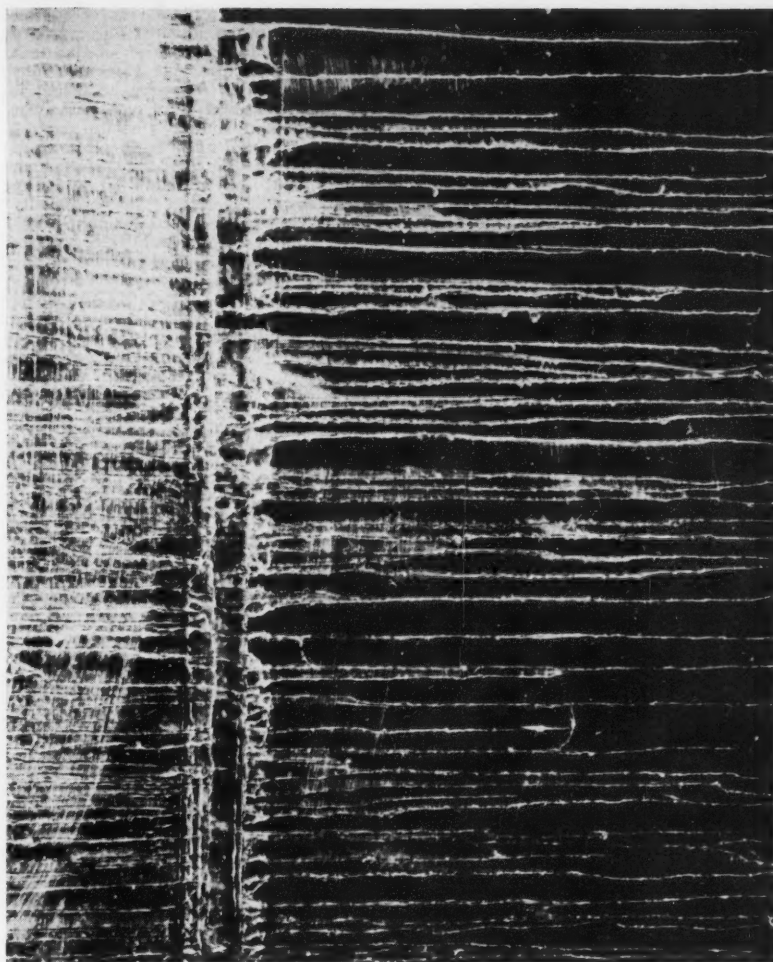


Figure 1—Stress cracking of a baked phenolic coating. Horizontal cracks were filled with a contrasting colored powder to show extent of the cracking. Progression of cracks developed in a circumferential direction around the vessel.

Survey of Application Data on Baked Phenolic Coatings Used in Process Industries*

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Union Carbide Chemicals Company
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Abstract

A summary of experience data concerning baked phenolics used as coatings in vessels storing chemicals, with emphasis on organics. Principal characteristics of phenolic coatings are reviewed. Sand-blasted, meticulously clean surfaces are stipulated. Necessity for proper drying between coats is underlined and the virtual impossibility of achieving pinhole-free coatings emphasized.

Thickness recommendations are made and proper backing procedure discussed, with a review of changes that take place during the baking cycle. Two methods of achieving pinhole-free coatings systems using metallic undercoating and organic overcoatings are described. Characteristic properties of baked coatings are summarized.

Chemical resistance of baked phenolic coatings to 18 classes of organic acids, anhydrides, aldehydes, alcohols, hydroxy compounds, organic esters, amines and others is tabulated. Cautions to be observed in cleaning are given. Coatings are not recommended for inorganic acids. Oxidizers or alkalis rapidly disintegrate them, and while recommended for use with all organic acids, they will not tolerate them if water is present.

Effect of formulation variations on performance are reviewed, and two kinds of coatings developing stress cracking failure are mentioned. Experience data are given for the use of the materials with 439 chemicals arranged in alphabetical order.

5.4.7

Introduction

UNLIKE many reports on coating materials, this article does not present in glowing terms the qualities of a new material for coating purposes. The discussion concerns a material extensively used for many years, the phenol-formaldehyde resins employed for coating purposes since 1935 in the author's company and before that time in other applications. However, proper use and methods for applying and testing this unique coating deserve review from time to time. The major intention of this writing is to provide a more complete listing of the areas of chemical exposure where the baked phenolic coatings may be used properly.

General comments regarding the application and testing of the coating are made, but the primary objective is to provide a comprehensive reference for its use as a coating in storage vessels, tank cars, drums, and other equipment with particular emphasis on organic chemical exposures.

If at times comments appear to be discrediting the coating, such statements
(Continued on Page 10)

* Revision of a paper titled "Baked Phenolic Coatings for Use in Process Industries" presented at a meeting of the Northeast Region, National Association of Corrosion Engineers, Boston, Mass., October 7, 1958.

TECHNICAL TOPICS

FOCUS
ON
INDUSTRIAL
COATINGS

Pages 9-29

(Continued From Page 9)
are made only to impress the reader with the importance of considering limitations as well as understanding the excellent properties the films exhibit. Articles on coatings too often describe the better properties of a material, and leave to the user expensive and discouraging trials and errors to find shortcomings.

Materials are not Simple

As is often the case with most other materials, there is a tendency to generalize and discuss baked phenolic coatings as a single material. This is not proper because, although differences probably are somewhat more subtle than those in

Test Extensively and Choose Carefully

a number of other coating systems, there are true differences among the various baked phenolic coating materials available now. The moral is: Test extensively and choose carefully!

Many modifications of the basic resin are used to formulate phenolic coatings. Also, the phenolics are modified to some extent with a plasticizer such as vinyl butyral or tung oil to improve the ductility of what is an inherently brittle resin. Among other modifications is the addition of pigments. Effect of pigmentation is known precisely only to the formulator, but considered solely from the user's standpoint, a phenolic film loaded sufficiently with pigment will have improved adhesion and lower permeability rate. Lateral strength in the film probably is increased also. This dis-

cussion is limited to a description of the basic phenol-formaldehyde or baking phenolic materials and will not discuss additions of epoxies, furanes or other materials.

Baked phenolic coatings have many of the attributes of a glass coating. Sheen normally is very high and if surface gloss and smoothness is a desirable characteristic, clear films can be applied which exhibit a glass-like surface. In many environments where solvent or other attack on the film does not occur, permeability of the film approaches that of a glass lining.

Applications are Numerous

Assuming that color, gloss, and other aesthetic points are of no interest and that the user is considering only service life, a realistic examination of application characteristics, testing and ultimate results to be achieved can be made.

These coatings can be applied successfully only on a surface which has had a meticulous sand-blast. An NACE No. 1¹ finish is required to provide a satisfactory surface, including a sufficient "tooth" to provide an anchor for the coating. This usually means that a profile with one to two mils of blasting depth should be realized during the surface preparation. This surface preparation makes possible successful application on aluminum, stainless steel, copper and materials with other than alkaline surfaces. Cleanliness is a major consideration when applying the material. The final film is so thin that particles of dirt may have a diameter equal to the film thickness. This requires careful removal for all dust particles and raw sand grit after sand-blasting.

The coating customarily is applied in a succession of thin films. While this is particularly slow and tedious using the clear materials, some pigmented formulations give at least twice the build per coat of the clear resin and are excellent as so-called primers or as a complete

system. Drying the film at 250 F is customary to remove solvents and prepare a dry surface for application of the next coat. When a sufficient thickness has been applied, the film may be tested if the user feels this is of value. A wet sponge tester normally is used.

If an excessive number of pinholes is present when the dry film is tested, another coat may be applied and the area retested. Defective areas usually will be found along weld lines. The number of pinholes along welded areas frequently exceeds the number in the greater area of the flat plate of a vessel. Some applicators handstripe welds before baking to reduce the number of pinholes in these areas.

What Thickness is Required?

Additional coats should be applied to the thin areas before curing. Film thickness before curing may be 6 or 7 mils, assuming an ultimate 5-mil coating, but under no circumstances should film thickness at this time be greater than 10 mils. Optimum thickness of phenolic coatings often is a subject of discussion. While standards specify a uniform 5-mil coating, experience shows that 2 to 3 mils provides excellent service in most applications. A practical thickness specification is a nominal 5 mils plus or minus 2 mils. Critical areas should be pointed out to the applicator and a minimum stipulated for them.

Excessive thicknesses must be avoided to prevent blistering during curing or excessive brittleness and possible stress cracking in service. It is assumed that application will be achieved without sags or runs exceeding the desired coating thickness. Building of the coating in corners, low areas, or elsewhere must be avoided to prevent excessive buildup.

When the film is satisfactory, curing may be achieved by baking at 350 to 450 F for varying periods. Because curing is a function of time and temperature, designation of a curing temperature has no

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TABLE 1—Chemical Resistance of Baked Phenolic Coatings for Use at Ambient Temperatures

Any exposure producing a corrosion rate approaching 0.02 ipy on substrate—NG OK—recommend. NG—not good, not recommended.		
Organic acids.....	OK	But limited in glacial acids*
Organic anhydrides.....	OK	
Organic aldehydes.....	OK	But choose the proper material*
Organic alcohols, glycols, glycol ethers.....	OK	But watch first homologue
Organic esters.....	OK	Except chelating compounds
Organic ethers.....	OK	
Organic ketones.....	OK	
Organic oxides.....	OK	All but ethylene
Organic amines, alkanolamines, amides, amines, nitriles, nitro compounds.....	OK	Except for first homologue
Halogenated compounds.....	OK	
Sulphur compounds.....	OK	
Phosphorus compounds.....	OK	
Silicon compounds.....	OK	
Hydrocarbons.....	OK	
Fungicides, herbicides, wetting agents, plasticizers, stabilizers, alkoxylated compounds, resins.....	OK	
Inorganic acids.....	NG	Except for special circumstances
	OK	For neutral and acid salts
Inorganic salts.....	NG	For basic or oxidizing salts
	NG	
Inorganic alkalis, halogens, peroxides.....	NG	

* Full cure of coating mandatory for first homologues.

particular significance. For field work, knowledge of the time required to bring the work up to heat and the time during which it is necessary to maintain the proper heat level must be determined by trial and error. The use of thermocouples on exteriors of vessels to measure wall temperature has proved advantageous, particularly in critical areas difficult to heat properly. Special precautions are required to prevent excessive dissipation of heat through welded attachments.

Fortunately, if pigmentation does not mask the effect, baked phenolics have a built-in color indicator which allows an estimation of the degree of cure achieved. Clear resins turn from a watery appearance to cherry red or amber when properly cured, and this color change also influences the appearance of formulations containing pigments in most instances. It is important to emphasize that the proper cure for use in the intended application must be known and achieved.

Simple drying, a distinct color change, wiping with rags saturated with acetone, or other similar surface tests will not provide reliable information concerning curing necessary to withstand the chemical service contemplated. In solvent service, this ignorance of the necessary cure has been responsible for more failures of phenolic coatings than any other reason. The designation of a proper curing condition for phenolic resins is a difficult compromise. Overbaking is undesirable because brittleness increases with increased baking temperature and time. Prolonged baking at high temperatures can cause degradation of the resin.

The 5-mil thickness of the baked film does not tolerate surface contamination with residual dirt or the introduction of dirt during the drying or coating period. This means that meticulous care is es-

sential on the part of the applicator to assure that all dirt particles are excluded during these critical periods.

Estimating Quality of Film

Assuming a phenolic coating has been applied which is resistant to the exposure and is in a satisfactory condition, what are the qualities of the finished film? First and foremost, it must be remembered the film is not pinhole-free. Do not attempt to specify baked films of this thickness in a pinhole-free condition. While it is possible to achieve such a condition, it is impractical to do so. Regardless of specifications written for a pinhole-free, phenolic-coated vessel, it remains true that pinhole-free baked phenolic coatings are accidental rather than predictable.

The proper time to pinhole test a phenolic coating is before final curing. At that time, a wet sponge pinhole tester, using distilled water with a non-ionic wetting agent, may be advantageous to show areas of light, discontinuous coating. The applicator then may apply another coat to help reduce the pinholes. However, results of pinhole testing at this time do not always assure that the coating condition will be the same after the final cure. Water is released during condensation of organic materials in the coating, and its release may produce small pinholes.

Also, because phenolic coatings are not particularly good wetting materials and consequently do not necessarily penetrate to the bottom of all cavities on the metal surface, gas covered by the film expands during the baking cycle and blisters the coating. Also, mechanical shrinkage of the film may produce small pores at random. These pores often are covered with one mil or less of film and thus allow pinhole testing

with excellent results. However, after a short period of service the coating develops pinholes. Actually, the number of pinholes in the coating probably will not exceed one per 2 or 3 square yards. Nevertheless, this is sufficient reason not to use thin baked coatings in severely corrosive environments.

Achieving Complete Protection

When a pinhole-free film is required, and certain advantages of baked phenolic coatings are desirable, there are two approaches to a solution. First, a coating of metal may be sprayed over the base followed by successive coats of the phenolic resin. This procedure gives excellent results and, although somewhat expensive, is satisfactory in providing a pinhole-free coating as far as the base metal is concerned. The sprayed metal will be exposed at small discontinuities in the phenolic film.

A second technique involves using the phenolic coating beneath one or two coats of an air-drying material. Careful use of a heavier film over the baked phenolic will guarantee a film of sufficient thickness to eliminate pinholes. These two specialized methods require a sound knowledge of the appropriate techniques, however, and should not be practiced by the novice without extensive investigation.

Patching Is Impractical

Once the film has been properly cured, patching is impractical. In one case out of five or so, a satisfactory patch of a baked phenolic material using the same resins may be obtained, but this percentage is too low to make it practical.

Some Characteristic Properties

There are many criticisms of the mechanical properties of this resin. When (Continued on Page 12)

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(Continued From Page 11)

sufficient modifiers are added to improve flexibility, chemical resistance of the film is then reduced. Dielectric strength is excellent, so similar materials have been used for years as insulating coatings on motor windings and in similar applications. Abrasion resistance is not very good because the film is hard and brittle. However, wear resistance is adequate if excessive pressure is not applied.

Thermal expansion characteristics are such that after repeated stressing on steel, crazing is said to occur, but this is not as serious a problem as would be

baked phenolic coatings while sufficiently cured films are entirely resistant.

Thousands of gallons of methanol are stored or shipped daily in baked phenolic-lined vessels and most experience long life with no trouble. However, if a baked phenolic coating is immersed in methanol for sufficient time (something less than two weeks) and the methanol is removed and followed by immediate steaming of the coating, catastrophic failure occurs. Loss of adhesion, blistering and sometimes stress cracking of the film occurs during this steaming procedure. Similar damage does not occur when hot air or water is used to clean the vessel. There is at least one baked phenolic coating available which, as well as can be determined, does not blister or degrade following the methanol-steam exposure.

The advisability of steaming phenolic coatings is often argued. While high-pressure steam cannot be tolerated, the use of low-pressure steam to remove residual products and odors has not been found detrimental in the experience of the author. Many vessels used for alternating chemical service for as long as 12 years with steaming between changes of commodity have not suffered any obvious damage to the film.

Organic esters present no problem in contact with the baked phenolic coating. However, if the ester is a chelating compound such as an aceto-acetate, corrosion products released from pinholes on a steel substrate may be sufficient to cause discoloration.

Ethers, ketones, and all organic oxides other than ethylene oxide, may be handled satisfactorily in contact with the baked phenolic coating.

Of the amines, alkanolamines, amides, and other nitrogen compounds, only the first homologs of the series must be tested and carefully examined for use in contact with a phenolic film. In most cases, it will be found inadvisable to use the baked phenolic film with the first homolog. The second homolog of the series ordinarily is acceptable as are all of those thereafter.

The halogenated compounds, sulfur compounds, phosphorus and silicon compounds, as well as aromatic or aliphatic hydrocarbons are adequately handled by a baked phenolic coating during storage or shipment. Most all fungicides, herbicides, wetting agents and large organic molecules are resisted by the baked phenolic coating with the exception of the more alkaline materials of this type. Baked phenolic coatings have essentially no resistance to alkalis; consequently only neutral or acid salts should contact the resin. Basic or oxidizing salts should be avoided. Generally, the coatings are not resistant to alkalis, halogens, and peroxides.

Not Good for Inorganic Acids

Phenolic coatings are highly resistant to hydrochloric acid in all concentrations and phosphoric and sulfuric acid until either heat or concentration produces an oxidizing solution. However, an earlier warning given at the bottom of Table 1 states that an exposure producing a corrosion rate greater than 0.02-inch per year on the substrate should not be considered. Pinholes will allow as rapid an attack on the substrate as that which would occur if no coating were there. Therefore, the fact that baked phenolic coatings are resistant to a 10 percent hydrochloric acid solution is strictly academic. There are special circumstances under which the baked phenolic coatings

may be used in contact with aqueous mineral acid solutions. In these cases it must be remembered that the attack on the substrate will be as great as if no coating existed, although the amount of metal actually lost will be small and contamination of the solution will be minimal. A more highly resistant substrate, such as copper, may be indicated for such applications.

The safe use of baked phenolic coatings in chemical process streams requires a thorough knowledge of the stream composition. Traces of oxidizing agents or alkalis can rapidly disintegrate the coating. Also, while resistant to all organic chemicals present, the coating has a limited resistance to the chemicals in the presence of water. This has been observed in solutions at moderate temperatures when organic acids are present in conjunction with a small amount of water. Thus, as with any other coating, it is imperative that the user be fully aware of the characteristics of the coating and test the particular phenolic to be used to assure resistance to the operating conditions.

Proper formulation of the phenolic coating must be emphasized. Figure 1 shows a type of failure not ordinarily found in phenolics but indicates that some variations will produce unsatisfactory resistance under certain conditions. The photograph shows stress cracking of a baked phenolic coating which occurred in pure solvent service. Two phenolic formulations have been found to develop this type of stress cracking failure. Only theoretical reasons for the failure can be given, but it is assumed most likely that the polymer is attacked at weak links in the chain by the solvent, releasing the stress developed in the phenolic film during the heat-curing cycle.

Table Lists Experience Data

Table 2 is a listing of organic chemicals which have been used in contact with baked phenolic coatings. These data show the extreme versatility of phenolic coatings in contact with organic molecules. All compounds listed are pure unless specified otherwise. The tests and use of the coating are limited to ambient temperatures.

These data are useful for determining whether or not a phenolic coating can be used practically in contact with chemicals in storage tanks, tank cars, or other services at ambient temperatures. Note two modifications in the table indicating that the coating may be resistant to the chemical but that its use would be impractical because of the pinholes in the film. Also, while it is known that certain pure phenolic coating formulations will resist a given chemical, all such materials available on the market may not be satisfactory. Exposures which differentiate among these formulations are indicated.

Information in this report and data presented in the tables is offered in addition to the recent report of Technical Committee T-6A-4 on Baked Phenolic Coatings. It is hoped that the two will give those interested a comprehensive view of the proper application and use of the materials.

References

1. Report on Surface Preparation for Steels for Organic and Other Protective Coatings, Second Interim Report, Technical Practices Sub-Committee 6-G on Surface Preparation for Organic Coatings, Publication 53-1, Natural Association of Corrosion Engineers, Houston.

Unmodified Baked Phenolic Coating Offers Best Solvent Resistance

anticipated. A surprisingly wide range of temperature fluctuations can be tolerated by the film on a steel substrate. The author has never observed cracking of the film by heating and quenching over a range of 400 F. Brittleness is the major problem. As an example, in tank car operation, the upper knuckle area eventually will craze and crack from the movement of the steel shell in this area over a long period of time.

Thermal stability of baked phenolic coatings is good and allows its use under all normal conditions of shipment and storage (140 F maximum). Any chemical exposure in excess of 180 F should be very carefully evaluated before using the coating. Temperatures in excess of 270 F should be avoided in any environment.

The unmodified baked phenolic coating offers the greatest solvent resistance of any coating material available today. In Table 1, general chemical resistance is categorized. Starting at the top under organic acids, it is shown that for general organic acid applications involving pure acids, the baked phenolic coating is acceptable. In the lower homologs, particularly acetic acid, the life of most baked phenolic coatings is limited. This does not mean, however, that they have no value for that service. A footnote to this category explains that the baked phenolic coating must be in a fully cured condition for exposure. In other words, a partially cured film will not resist attack.

Organic anhydrides normally present no difficulties, but organic aldehydes present a problem. The aldehydes are, of course, among the most potent of organic solvents, and it is in this region that the differences among baked phenolic coatings can be most readily determined. Do not assume that for aldehyde service, particularly in the lower homologs, that all baked phenolic coatings are equivalent.

The alcohols, glycols, glycol ethers and other hydroxy compounds are acceptable for baked phenolic coating use, but there are two chemicals, again the first homologs of this series, which deserve special consideration. Ethylene glycol will rapidly remove undercured

TABLE 2—Baked Phenolic Coatings (5 mils) Practical for Shipment and Storage of Chemicals*

[illegible]

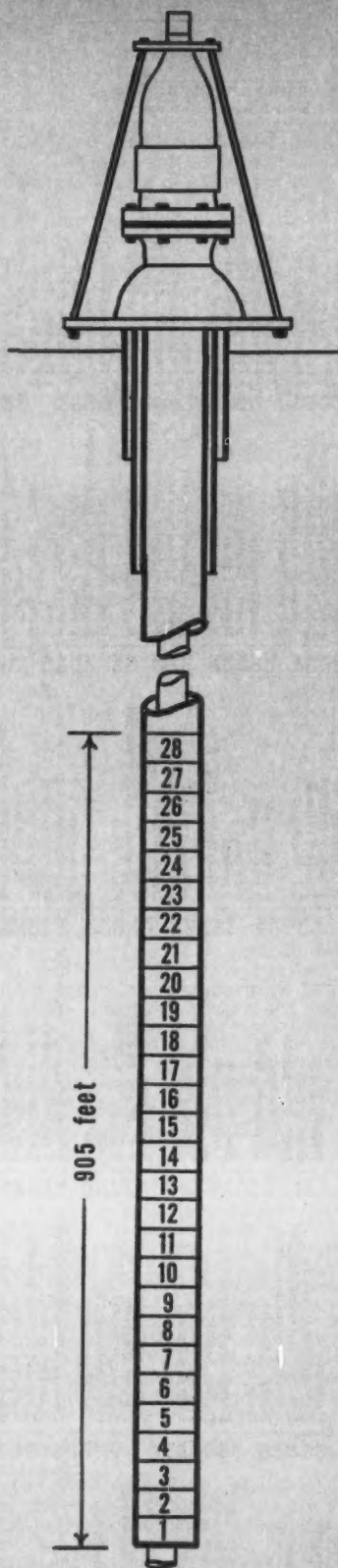
- * Normal conditions of shipment and storage not exceeding 140 F.
-) Some phenolics not satisfactory. Use with care.
-) Coating resistant but should not be used.

Epoxies Give Good Service in Well Casing Coating Test*

William R. Lambert
United Fuel Gas Company
Charleston, West Virginia

Abstract

Gives brief description of coatings test on well casing exposed for 18 months in West Virginia. Conclusion is made that epoxies gave best service. Tubular data give coatings tested and well log on test well.
5.4.5, 8.4.3



ELEVEN COATINGS were applied to sections of an 8-inch well casing to determine which type coating would be best to protect casing. The bottom 905 feet of the 2536-foot casing was used as the test area. See Figure 1 and Table 1.

This casing was left in the ground for 18 months. The 2536-foot string weighed 40 tons. About 141 tons of pull were required to lift the casing off the bottom, indicating that there was considerable cavings and friction.

As the coated section of the casing was pulled, coatings on each joint were inspected, tested and evaluated.

Examination showed the epoxy coatings to be more effective for well casing

than the other coating types. Two of the epoxies showed excellent adhesion and covered more than 90 percent of the test pipe, giving an effective seal and insulation between the casing and surrounding environments. (See Table 2 for well log showing soil types.) Thus the amount of cathodic protection required would be reduced. This 90 percent coverage was after the casing had been lowered and pulled out. About half the damage probably was done when the casing was lowered and pulled.

These epoxies were applied in the field. If applied at the mill, the coatings probably would have shown better performance.

From this test, it was concluded that mastics, tapes and enamels are not the most satisfactory coating for well casing.

The well on which this test was run is in McDowell County, West Virginia, on the dry fork of the Tug River.

Figure 1—Test areas on well casing showing pipe sections at bottom of string used for evaluating eleven different coatings. See Table 1 for names of coatings.

TABLE 1—Types of Coatings Used on Casing Test

Coating Type No.	Coating	Manufacturer
1.....	epoxy	Pittsburgh Chemical
2.....	epoxy	Dearborn Chemical
3.....	Coating and wax wrap combination	Dearborn Chemical
4.....	cold applied epoxy mastic	Royston Laboratories
5.....	wax, joint compound paint	Dearborn Chemical
6.....	asphalt mastic coating with glass wrap	Royston Laboratories
7.....	wax pipe wrap with primer	Dearborn Chemical
8.....	PVC tape with primer	Minnesota Mining & Mfg.
9.....	plastic cold set resin	Wisconsin Protective Coatings
10.....	plastic cold set epoxy with inhibitive pigments	Wisconsin Protective Coatings
11.....	PVC tape with adhesive primer	Plicoflex Company

TABLE 2—Coatings Used on 28 Joints of Pipe

Joint No.	Type Coating*	Joint No.	Type Coating*
1.....	Bare	15	Bare
2.....	Bare	16	8
3.....	6	17	Bare
4.....	4	18	7
5.....	4	19	Bare
6.....	Bare	20	1
7.....	2	21	1
8.....	2	22	1
9.....	Bare	23	Bare
10.....	3	24	5
11.....	3	25	Bare
12.....	Bare	26	half 9, half 10
13.....	6	27	Bare
14.....	6	28	11

* See Table 1 for types of coatings used.

TABLE 3—Well Log

To	To	To
Soil 11	Sand 812	Lime 1878
Sand 118	Slate 816	Red Rock 2016
Coal 120	Sand 892	Gritty Lime 2048
Sand 169	Slate 913	Red Lime 2060
Coal 171	Sand 974	Slate and shells 2100
Slate and shells 248	Lime shells 1041	Red Rock 2120
Coal 251	Sand 1113	Red lime 2190
Slate and shells 346	Slate and shells 1124	Red rock 2225
Sand 407	Red rock 1178	Lime 2316
Slate and shells 632	Slate and shells 1212	Hard gritty lime 2324
Sand 680	Black lime 1421	Lime shells 2458
Coal 683	Slate and shells 1606	Slate and shells 2505
Slate 695	Sand haven cliff 1718	Hard lime 2530
Sand 745	Slate 1790	Sand
Slate and shells 786	Sand 1820	

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1878
2016
2048
2060
2100
2120
2190
2225
2316
2324
2458
2505
3530



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Special Coupon

Used in Testing Liner Coatings*

Oliver W. Siebert
Monsanto Chemical Company
Monsanto, Illinois

Abstract

Because the coupons usually employed for atmospheric tests of coatings do not give reliable information when used for testing coating for liners, advantages of several special configurations were explored. These included spheres, various configurations of the torus and the Moebius shape. Author concludes that the Moebius configuration apparently gives the most reliable information of any of the shapes tested. Experimentations is being continued to establish whether or not one configuration is better than another.

5.4.2, 2.3.7

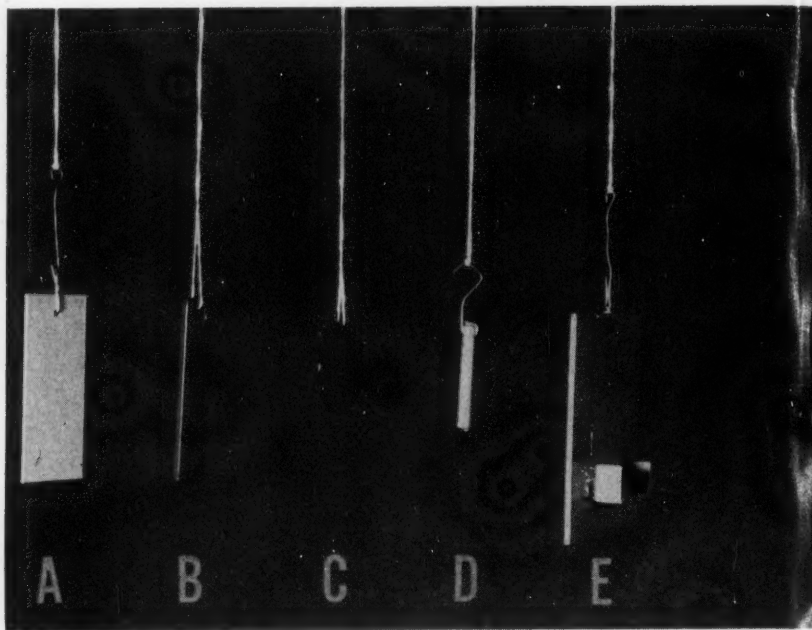


Figure 1—Typical shapes and configurations for coating specimens and supports used in accelerated tests for maintenance coatings. From left to right they are (a) thin rectangular coupon, (b) thick rectangular coupon, (c) thin circular coupon, (d) cylindrical specimen, (e) KTA panel and (f) spherical shape.

ATMOSPHERIC EXPOSURE test systems are not fully applicable to the study of internal barrier coatings. In practice, few if any satisfactory methods exist for evaluation of construction materials in these latter exposures. Actually, the only systems available have been the use of test coupons of the standard flat configuration and cylindrical rods. Figure 1 illustrates typical panels of these shapes.

Accelerated tests to determine the suitability of maintenance coatings for atmospheric exposure are routine and evaluations are possible by engineering techniques. In such studies it is the desire as well as the tool to simultaneously verify the chemical resistance of the coating as well as its tendency or susceptibility to local and premature failure. Tests and test panels (such as the KTA panel, shown in Figure 1e) are designed to duplicate conditions of coating weakness found in structural systems, e.g., crevices and hard to paint areas, sharp corners, edges and small radii, weld splatter and areas which are difficult to provide an adequate surface preparation.

In the case of internal barrier coating surveys, the initial purpose is to determine the chemical resistance of the coating to the environment. Once this has been determined, test conditions can be added

to evaluate quality of the then identified chemical resistant coating to the physical condition of the vessel. Except for prevention of product contamination, barrier coatings must be holiday free. This dictates construction with minimum irregularities, protrusions and crevices, making the "local failure" test unnecessary in most studies.

While surfaces of a flat panel offer a more realistic test surface than a cylinder, sharp corners and thin edges exaggerate a condition found to a lesser degree in the hemispherical ends of a cylinder. In both systems, a support hole or wire introduces additional variables into evaluations.

The sphere or button, studded from one point over a fluorocarbon gasket onto a metal hanger, has been long used for testing glassed-steel.¹ This sample design and support method is shown in Figure 1f. Possible leakage past the gasket is almost as big a weakness as the requirement or even the existence of an economical metal for holder construction.

While literature abounds with discussions of the many variables in coating performance testing,²⁻⁶ none of them is of overriding significance unless a satisfactory panel is available, insofar as laboratory tests are concerned. While corrosion testing by its very nature precludes complete standardization,⁷ something should be done to advance present techniques.

* Revision of a paper titled "Special Purpose Panels for Evaluation of Internal Barrier Coatings" presented at a meeting of the North Central Region, National Association of Corrosion Engineers, October 19-20, 1960, Milwaukee, Wis.

Shapes

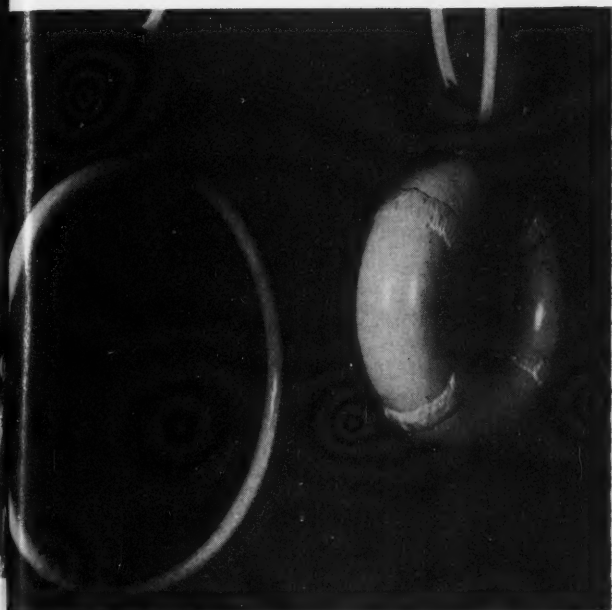


Figure 2—Two types of torus (or doughnut) specimens and supports. On the left is an original narrow torus made of $\frac{3}{4}$ -inch diameter steel rod formed into a 10-inch circle. On the right is a thick torus made by joining four 2-inch welding elbows into a circle.

Purpose of this article is to describe several special geometric shapes used at the W. G. Krummrich Plant of Monsanto Chemical Company in efforts to overcome inadequacies of standard test panels in the evaluation of internal barrier coatings.

Experimental Procedure

The first step was to accept the cylindrical bar as an adequate sample if something could be done about the hanger problem. Coating the inside of the support hole, use of special alloy wires or applying the coating over the sample and the wire are equally unattractive. It was reasoned that an infinitely long cylinder with no ends was a solution. In practice, a torus^{8,9} or doughnut met the requirements. Support became a simple matter of a sling of chemical resistant non-metallic strap or tubing looped through the doughnut hole and attached outside the vessel. A standardized design of $\frac{3}{4}$ -inch diameter steel rod formed on a 10-inch major diameter, has been used for about three years. Figure 2a illustrates the torus and its support system. It was acknowledged that a small cylinder (in this case $\frac{3}{4}$ -inch diameter) did not offer as representative a surface as a flat panel.

The next step was to enlarge the cross section to more nearly approach the desired flat surface. Welding four 2-inch welding elbows into a torus satisfied the surface requirement. This second torus design is shown in Figure 2b. The thick design reduced the



Figure 3—Moebius coating panel is formed from a long rectangular strip with one end half twisted before joining. The shape and accessibility to all surfaces of the panel permit the panel being brushed, trowelled or sprayed because every surface is unobstructed to at least a 90-degree view.

minor diameter so it became difficult to coat the inside surfaces with a representative thickness by brush, trowel or spray. To enlarge the doughnut to overcome this difficulty would have made the test panel ridiculously large.

The same reasoning which led to development of the $\frac{3}{4}$ by 10-inch torus, i.e., a cylinder of infinite length (or one with no ends), was applied to the flat plate coupon. Benefits of the desirable flat surface without the undesirable edge effect, could be incorporated by altering the rectangular cross section into an ellipse. Also, such a circular band or rim would not need support holes or wire because a sling could be used. However, difficulties experienced with coating the doughnut hole in the thick torus led to a decision not to test the design. This step, however, was a necessary preliminary to the evolution of the Moebius band.⁽¹⁾

The Moebius panel (Figure 3) is made by forming a long rectangular strip into a circle, as with the circular rim, except that one end is given a half twist before it is joined.⁽²⁾ The Moebius geometry, long an interesting mathematical paradox, has been the exclusive property of practitioners of mathematical

(Continued on Page 18)

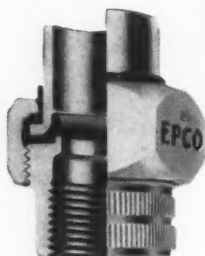
⁽¹⁾ August Ferdinand Moebius, 1790-1868. German astronomer and mathematician.

⁽²⁾ It is important that this 180 degrees of twist be equally distributed around the circumference so it will not be misshapen by being made flat, which concentrates most of the twist in a small zone.

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Moebius Band Has One Side, One Edge

(Continued From Page 17)

games.^{10,11} A Moebius band is described as a figure with only one side and one edge.

This oddity overcame the faults of the almost desirable elliptical cross sectioned circular rim panel. A Moebius panel can be brushed easily, troweled or sprayed using standard techniques because "every surface is unobstructed to at least a 90-degree view."¹⁰ It can be said that, in practice, a Moebius shape, like a solid sphere, has only an outside surface, but unlike a sphere, it has a hole for a sling which can be used for support.

The most singular benefit of the Moebius design is that all areas on a panel are exposed to the environment without obstruction.

Moebius panels used have a 10 to 12-inch outside diameter. The bars are elliptical in cross section with a 5/16-inch minor and 1 1/4-inch major axis.

Conclusions

In spite of extensive experience with Moebius panels and the logic of its advantages over other panels, it is not used exclusively. Tori, standard flat and cylindrical shapes sometimes are exposed as controls along with the Moebius panels.

Experience in this testing program indicates coatings can be tested for suitability as internal barriers better with Moebius panels than with other types.

Acknowledgments

The author thanks E. G. Wood, Materials Engineer, B. L. Buatte, Engineering Aide and R. C. Townsend, photographer, Monsanto, for their assistance in testing and recording test panels. Appreciation is also extended to A. D. Dohr, Nooter Corporation for fabrication of steel Moebius panels; J. W. Cushing, Carbolite Company and W. T. Woodson, St. Louis Metallizing Company for application of specialty coating systems.

DISCUSSIONS

Question by L. W. Gleekman, Wyandotte Chemical Co., Wyandotte, Michigan:

Is there not a problem in the lack of similarity between the Moebius panel and certain features of tank construction such as smooth (not flush) welds, right angles, flexing of floor plates, roof supports, etc.?

Reply by O. W. Seibert:

No. In the cast of internal barrier coating surveys, the initial purpose is to determine the chemical resistance of the coating to the environment. Once this has been determined, test conditions can be added to evaluate quality of the then identified chemical resistant coating to the physical condition of the vessel.

Question by Charles W. Ambler, East St. Louis, Illinois:

If the Moebius can be suspended with a sling, cannot a sphere also be so suspended and thereby eliminate difficulties of gasketing now experienced with button spheres?

Reply by O. W. Seibert:

The Moebius Panel can be supported by a single, simple wire, tube or narrow strap sling of a resistance metal or TFE plastic, which in turn offers little obstruction to the coating exposure area. A sling or net of wire or plastic to support a sphere with the same integrity would be complicated, difficult to make and would bring about a major reduction in the free area of coating exposure.

Questions by Robert L. Collins, Evergreen Park, Illinois:

1. What is the approximate length of the rods used in forming your test panels?

2. How would you check for film holidays and for pinholes on the immersion test panels?

3. Which type of holiday detector do you prefer for testing film for holidays of tanks? Wet sponge vs electric spark tester?

Replies by O. W. Seibert:

1. The Moebius bar is 36 inches long, not counting the excess needed for holding during feeding into the forming die.

2. We have used both electric spark testers and wet sponge holiday detectors but prefer the spark tester for test samples. Spark testers do not all require a grounding contact through the coating as does the wet sponge unit which in turn must be repaired but cannot be tested.

3. We prefer to use the wet sponge type holiday detector for testing coatings and films inside tanks; the required grounding connection can be made to the outside of the vessel without damage to the coating itself. In the cases of glass lined steel tanks and units lined with fairly thick coatings and mastics, it is necessary to use the conventional spark testers.

Comment by William A. Hess, Standard Oil Company of Ohio, Cleveland, Ohio:

We have used a sensitive ohmmeter with a wet sponge to make a more sensitive instrument to determine holes in a coating.

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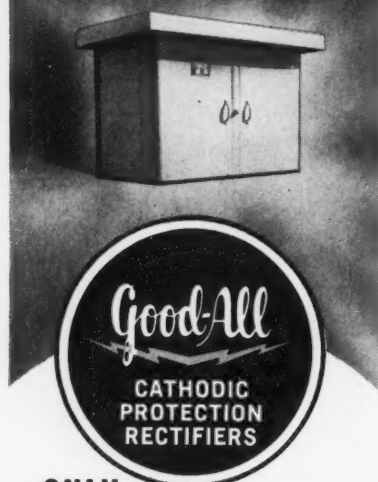
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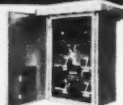
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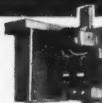
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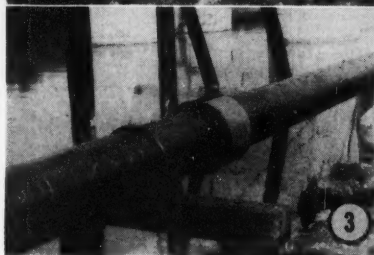
Kurt A. Gruber

*Chemical Fire and Rust Proofing Corporation
Great Neck, New York*

Figure 1—Sandblasting on 20-inch line in "good terrain." Other portions were in tidal swamp, or suspended beneath bridges.

Figure 2—Inspecting surface of pipe for loose coating, deep pits. Sandblasting often penetrated pipe in areas where corrosion was greatest.

Figure 3—Showing Dresser coupling encased in fiber mold filled with hot tar enamel.



RECONDITIONING of the exterior protection of the 130-mile, 18 and 20-inch water line between Florida City, Fla. and the Key West Naval Shipyard involved installation of cathodic protection on portions underground or under water, and extensive cleaning, patching and recoating of that portion above the ground and water level.

The line, installed in 1941, belongs to the United States Government, which operates it through the U. S. Navy's Aqueduct Office at the Key West yard. The Florida Keys Aqueduct Commission handles water sales to civilian consumers. The line supplies 3 to 6 million gallons of water a day to government installations and to civilian consumers along its route.

Because the extremely aggressive coastal marine environment was causing so many leaks, the Navy decided to recondition the areas exposed to the atmosphere and put cathodic protection on the remainder. Chemical Fire and Rust Proofing Corp., Great Neck, L. I. obtained the largest of four reconditioning contracts.

Originally protected outside with a coat of coal tar enamel and one wrapping of pipeline felt, some areas at or near the surface were in a bad state of repair. Leaks were so frequent that major reconditioning became necessary. However, because some of the exterior coating was in good condition,

the contract called for removal of loose and poorly bonded coating, which ranged between 10 and 100 percent of the surface.

The pipe was tapped and chipped, all bare and rusty pipe was sandblasted and if pits were sufficiently deep, repairs were made either with welded patches or epoxy resin filled with metal. Nearly 1000 Dresser couplings were repaired by replacing deteriorated rings and bolts.

Sandblasted areas were primed immediately, to prevent rusting, and then an additional coat of prime preceded the application of hot bituminous enamel. No wrapper was added but the entire surface of the pipe received three coats of cold bituminous coating, the last of which was pigmented with aluminum to give the finished pipe a reflective surface. Average thickness of the finished system was 1/2 inch. Dresser couplings were contained in fiber molds which then were filled with hot coal tar enamel.

The Navy recognized that the repairs made were not necessarily the best that could have been done. It was necessary, however, to continue using bituminous coatings because of the piece-meal reconditioning. About 1000 feet of pipe was sandblasted to bare metal, and on this length a variety of coatings was applied for testing.

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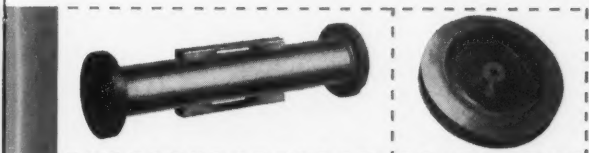
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Effect of Some Application Variables on

Maintenance Coating

Introduction

AT THE 1956 National Association of Corrosion Engineers Conference a paper on "Reducing Maintenance Painting Costs in the Chemical Industry" was presented by the authors.¹ A curve shown in this paper illustrated the significant reduction in annual maintenance painting costs of the du Pont Company which had been accomplished by putting into wide use what was considered to be good practice—such things as proper and efficient surface preparation and application and proper selection of materials.

These practices generally have been accepted and implemented in du Pont plants where corrosion is a problem. This is evident in Figure 1 from the upper curve which shows a rapid drop in cost since this 1956 report, which covered costs from 1951 through 1954. The cost of decorative painting, where repainting is dictated by appearance requirements only, is shown by the lower curve which represents painting costs on those plants with noncorrosive atmospheres. The goal is to bring the cost of protective painting down to this lower level. The fact that the upper curve is leveling out before reaching this goal indicates that current know-how has been put into practice and that more work is required to improve performance of protective coating systems.

Earlier attempts to get longer active service life involved using materials which produce films with better chemical resistance. Experience has shown that many of these materials, when applied to equipment and structures under field conditions, frequently do not perform as well as laboratory evaluation indicates that they should.

Failures of some systems were blamed on poor application. Also, it was observed that application requirements of some materials were extremely critical—so much so that it is doubtful that they can be met in practical and economical maintenance painting. So, it was concluded in evaluation of maintenance coatings, the ease of applying a film of good integrity must have equal weight with other properties, such as chemical resistance.

Equipment and Procedure

This study reports an attempt to develop a method for evaluating ease of application of a coating. Thickness and continuity of films applied by proper spray technique under ideal conditions were determined. Also, variables such as distance from spray gun to surface, air caps, and atomizing air pressure were

introduced and the resultant effects on the applied coating were determined. In this manner the limits of application variables that can be permitted without significant detrimental effect on the applied coating are established. These limits constitute what are termed "application tolerance" of a coating material.

Controlled Spray Operation Equipment

Because the variable least controllable in spray application is operator technique it was necessary to devise a controlled spray operation in which this variable would be eliminated. To accomplish this an electrically driven traversing mechanism capable of moving the spray gun at rates from 72 to 250 feet per minute was obtained. This equipment consists of an automatic spray gun, an air pressure transformer, a two-quart pressure cup, suitable hoses, and an air-operated toggle switch to control the gun. The remainder of the equipment provides the means for positioning the target. A test panel is mounted on a vertical rack which can be set at distances from 0 to 20 inches from the gun, and also can be raised or lowered in 2-inch increments or multiples thereof to provide control for overlap of successive passes.

With this equipment, the effect of variables can be investigated, such as distance of spray gun to surface, atomizing air pressure, air caps, fluid flow rate, gun speed, overlap between passes, and multiple coats.

Following is a detailed procedure used in studying the effect of distance on thickness and continuity of an applied film. Other variables can be studied by modifying the procedure accordingly:

1. The coating is prepared for application by mixing, including addition of catalyst if required, thinning as necessary for proper spraying viscosity, and straining. Air and material temperatures are maintained in the range 70 to 80 F.

2. The coating material is put into the equipment and pressure is adjusted to give a fluid flow rate of 16 ounces per minute. Atomizing air pressure is regulated to give satisfactory atomization and the spray pattern is adjusted to an 8-inch fan at eight inches from the gun. For tests reported here, an automatic spray gun was used, fitted with an FX fluid tip and needle and a No. 54 air cap.

3. The test panels, 8 by 30-inch by 24 gauge, pickled and oiled carbon steel, are solvent washed, dried and wiped free of dust prior to painting. Starting at the top of the panel, single passes are made across the surface at a gun speed of 166 feet per minute, the panel being raised 4 inches after each pass. Panels are sprayed at 8, 12, 16 and 20 inch gun-to-panel distances.

4. Panels are allowed to air-dry for

one week and dry-film thickness is measured with a thickness gauge.

5. Electrical resistance of the dried film is measured. Acrylic resin rings, 4 inches in diameter and 1 inch high, are sealed against the panel with stopcock grease. These are filled with a solution of 1 percent sodium sulfate and a wetting agent. The panel is connected through an ohmmeter to a platinum electrode. When the solution has been in place 3 minutes, the electrode is immersed in the solution to impose a 30-volt direct current potential across the film. The resistance of the coating is recorded as indicated on the ohmmeter. This measurement has been used as the principal criterion for establishing the maximum distance at which a spray deposited coating will form a continuous film.

Discussion

Effect of Distance

Experience indicates that even when supplied with good equipment properly adjusted, a painter's most frequent mistake is inadequate control over the distance of the spray gun from the surface being coated. Most of the work in this study, therefore, has been to determine performance of a coating material relative to this variable. Data in Figure 2 show the effect of spray distance on film thickness and electrical resistance of four metal primers. In the chart on the left, film thickness versus distance is plotted, and on the right, resistance versus distance is shown. There are considerable differences among the dry-film thicknesses of the four coatings when sprayed at the 8-inch distance, which is generally accepted as proper distance for spraying; however, increasing the distance does not significantly reduce thicknesses. There also are considerable differences in resistances among these coatings when sprayed at 8 inches; however, in this case, increasing distance significantly reduces resistance of two coatings. Reduced resistance means increased current flow and indicates holes which allow the solution to penetrate to the steel.

Minimum acceptable resistance has not been firmly established, but a minimum range of 500,000 to one million ohms is considered to be desirable. This range is shown as a shaded area in accompanying figures. With this as a guide, it is obvious that Material B does not provide an acceptable film at any spray distance. In contrast, Material A shows good resistance to all distances, which indicates films of high integrity. Materials C and D are between these extremes. Material C becomes unacceptable after exceeding a distance of 12 inches. Material D falls below acceptable limits when sprayed at a distance greater than 16 inches. Other things being equal,

* A paper presented under the title "Application Tolerance of Protective Coatings," at the 16th Annual Conference, National Association of Corrosion Engineers, Dallas, Texas, March 14-18, 1960.

J. R. Allen, F. W. Thompson
and
M. L. Monack
E. I. du Pont de Nemours & Co., Inc.
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Performance*

Material A would be the logical first choice on the basis of these data, with Material D being a fairly close second.

Figure 3 shows the effect of distance on three catalyzed synthetic resin coatings of the same generic type. Again thickness is shown in the left chart and resistance in the right. There are appreciable differences among the dry-film thicknesses of the materials, and increasing the distance noticeably reduces the thickness for all three. Resistance measurements indicate spray-applied films of Material B are acceptable at all distances sprayed, but those of Material A and C are unacceptable at any distance. It is interesting to note that although Material A produces the highest film thickness, it has the lowest resistance. Of particular significance here is the fact that materials of the same generic classification may not provide the same degree of film integrity.

Figure 4 shows results obtained with three different generic types of protective coatings. Material A is an oleo-resinous type, Material B is a catalyzed resin type, and Material C is a synthetic resin solution type. As indicated by the resistance data on the right,

Materials A and B would be acceptable for maintenance painting and Material C would not be acceptable.

Many other variables in spray application affect the quality of the deposited film. On a limited basis, the effect of some of these have been studied.

Atomizing Air Pressure

Figure 5 shows the effect of atomizing (Continued on Page 24)

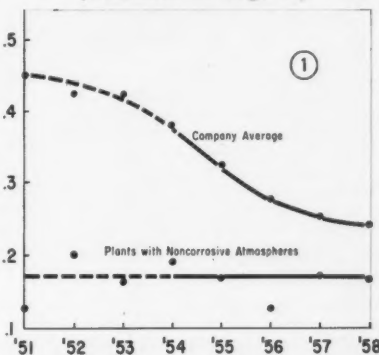
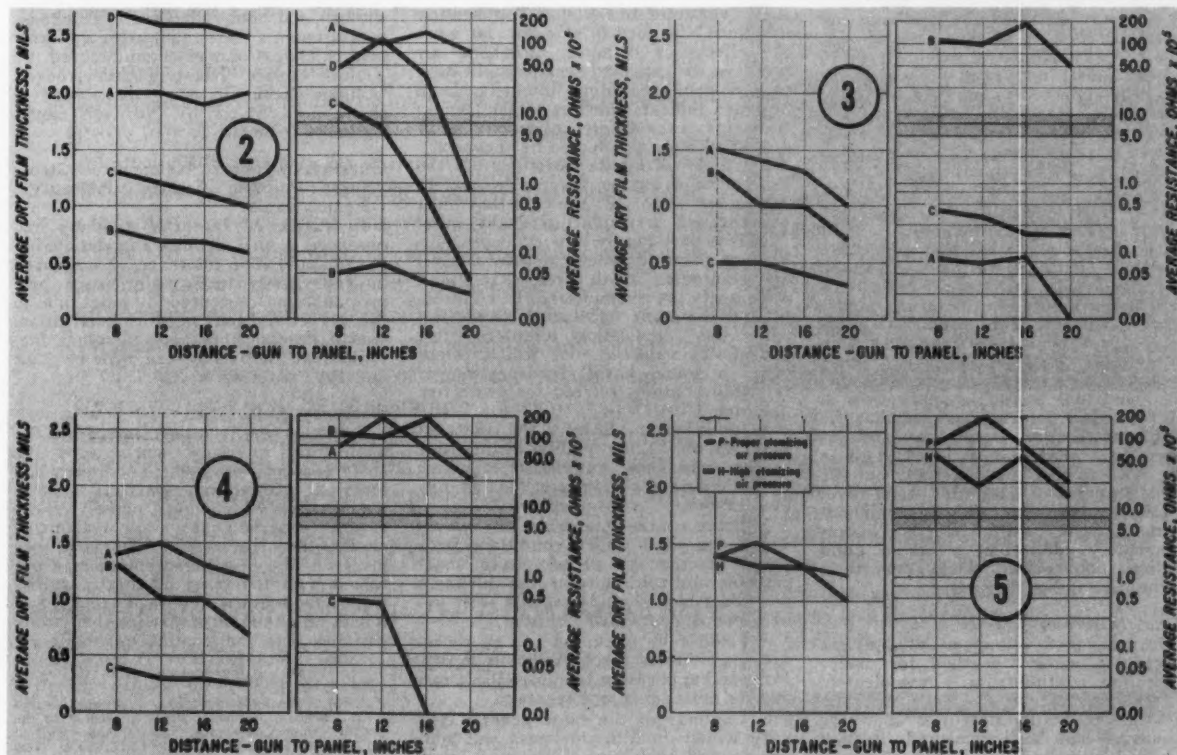


Figure 1—Annual maintenance painting cost as percent of company investment.

Figure 2—Effect of spray distance on film thickness and electrical resistance of four metal primers. Minimum desirable resistance range is shown in shaded area. Figure 3—Effect of distance on three catalyzed synthetic resin coatings of same generic type. Thickness shown on left; resistance on right. Figure 4—Results obtained with three generic types of protective coatings: A is oleo-resinous, B is catalyzed synthetic resin, C is solution type synthetic resin. Figure 5—Effect of atomizing air pressure on an oleo-resinous coating.



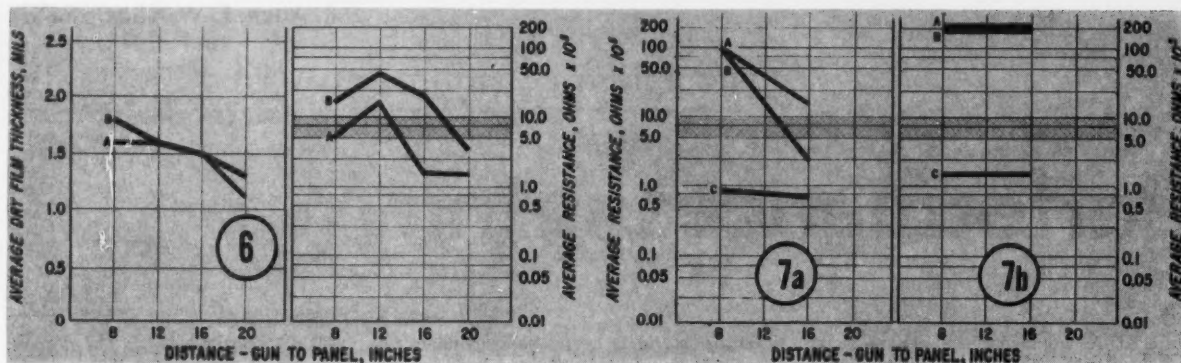


Figure 6—Effect of air caps on heavily pigmented metal primer. Figure 7—Chart 7a shows resistance of standard application of a cata-

lyzed synthetic resin coating. Chart 7b shows resistance on a double application.

(Continued From Page 23)

air pressure on a material which generally exhibits excellent application characteristics. Curve P shows the results obtained when the coating is spray applied with proper atomizing air pressure and Curve H with atomizing air pressure 20 psi higher than that considered proper. Although films deposited under both conditions have adequate thickness and good resistance, there is an indication that the higher atomizing air pressure has a detrimental effect. It would be expected that this detrimental effect would be much greater with a coating having poorer application characteristics.

Air Caps

Figure 6 shows results obtained when a heavily pigmented metal primer was spray applied with two different air caps. The better film is obtained by using Air Cap B. Also, resistance data show that with Air Cap A the maximum satisfactory distance for applying an acceptable film is 12 inches. With Air Cap B this distance is extended to 16 inches. These last two figures, which cover the effect of atomizing air pressure and air caps, illustrate that minor differences in film thickness and resistance of a spray-applied film are detected readily by this test method.

Double Application

Data presented thus far have been based on the standard test procedure described earlier and represent a single coat application. Double applications were made with three materials to determine whether significant differences can be detected for coatings applied in this manner. Figure 7 shows resistance data for a standard application in the left chart and a double application in the right. It would be expected that the double application would be considerably better than the standard. This is true with two of the materials, but the third remains unacceptable even with a double application. This is significant in maintenance painting where economics make it desirable to obtain good quality and required thickness with a minimum number of coats.

Visual Inspection

During the development of the test procedures another method for evaluating film continuity was investigated. A free iron detection solution was used to locate discontinuities in areas where resistance had been measured. Results obtained correlated well with those of

the standard method where electrical resistance measurements indicated the films to be unacceptable. However, this method was not sensitive enough to detect differences among acceptable films.

Summary and Conclusions

A protective coatings program has produced gratifying results in reducing the du Pont Company's maintenance painting costs. However, continuous effort must be expended to put better and better tools, techniques and materials in the hands of the painter if continued improvement is to be realized. In particular, the painter must be provided with materials that give him a reasonable chance of obtaining an adequate protective film.

Equipment has been described and a test procedure outlined with which coating materials can be investigated as they are affected by spray application variables. At du Pont, permissible limits of these variables are called "application tolerance." Studied briefly thus far were the effects of distance, atomizing air pressure, air caps and double application on the deposited film's integrity. Data obtained indicate the test method effectively measures differences among spray deposited films as affected by these variables, and will allow predicting (1) the ease of applying an acceptable coating in this respect or (2) the care that must be exercised to produce a quality film.

This is particularly important in maintenance painting where structural steel and equipment of all sizes, shapes and complexity are encountered. In conjunction with other laboratory screening tests, the "application tolerance" test provides a valuable tool which establishes a sound basis for accepting or rejecting coatings offered for protective painting.

In addition to showing the effect of variables on coating quality, quantitative results have been provided from which the following important conclusions may be drawn:

1. Some coating materials, even when spray deposited under conditions generally accepted as proper, have unacceptable film continuity or film thickness or both, which should preclude their use as general protective coatings.
2. Good film thickness is not necessarily a criterion for high film integrity. For good application tolerance these two factors must be complementary.
3. Coatings of the same generic type vary widely in film thickness and continuity and they cannot be used inter-

changeably on the basis of similar composition; "application tolerance" is a property of the individual coating formulation.

Field performance data are available on some of the coatings investigated in this study and good correlation exists between the results of this test and field experience. Materials which perform well in the field show good "application tolerance" in the test and, conversely, poor field performance confirms poor tolerance results.

DISCUSSIONS

Question by Joseph J. Picarazzi, Cities Service Refining Corp., Lake Charles, Louisiana.

Film Thickness spreads of one half mil are shown in several charts. Would you please give information on your dry film measuring method?

Reply by J. R. Allen:

Applications were made on clean, smooth, flat cold rolled steel. Thickness measurements were made with a Mikro-test thickness gauge manufactured by Elektro-Physik, Nix and Steingroever, Cologne-Riehl, Germany, distributed in the United States by Nordson Corp., Amherst, Ohio.

Question by John D. Keane, Steel Structures Painting Council, Pittsburgh, Pennsylvania:

You mentioned that the company had observed a well defined correlation between application tolerance, as measured in your study, and maintenance performance, as measured in paint life in the plants. In making this correlation, was it necessary to keep all other factors equal, such as generic type of paint and type of environment?

Reply by J. R. Allen

Some of the coatings tested in the application tolerance work were the same coatings with which we have had long and varied experience as maintenance paints on chemical plants. Where several generic types were reasonable choices for the service and exposure involved, the best performance was obtained with the same coating materials that have shown the best application tolerance. In these comparisons, the only variable was the coating material.

Reference

1. M. L. Monack, H. W. Shockley and J. R. Allen. Reducing Maintenance Painting Costs in the Chemical Industry. Paper presented at the 12th Annual Conference, National Association of Corrosion Engineers, March 12-16, 1956, New York, N. Y.



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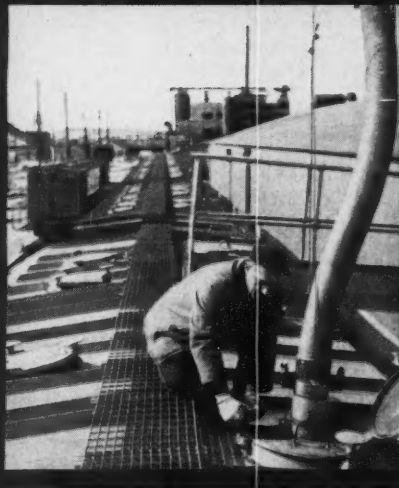


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CR61-5

A MAINTENANCE coating manufacturer must assume stringent responsibilities. First, he must have a thorough understanding of industrial corrosion problems which enables him to know why ordinary paint fails in severe plant areas. An example of his requirement is found in the question: "Why do coatings fail time and time again over steel in a sulfide atmosphere?" The rust looks the same but even when applied over sandblasted surface coatings last only a short time. The reason for failure is that sulfide contamination remains on the steel after sandblasting. The manufacturer who recommends a coating for this purpose must know this, and the remedy, too. The remedy is to oxidize the sulfide from the steel after the original blast and then reblast to clean metal. Understanding the problem and knowing the answer are responsibilities of a technical coating manufacturer.

Effective Research Essential

A successful maintenance coating manufacturer cannot be just a formulator and must know there is no quick and easy way to originate a coating satisfactory for severe industrial exposures. After a corrosion problem is recognized, a research project of several months or years duration must be carried out if a reliable answer is to be found.

For example, when inorganic zinc coatings were first introduced into this country from Australia the only method of curing them into an effective coating was to "stove" them. Obviously, this procedure was impossible for large, new or existing structures. So, a research project was started to find a method of applying these coatings to existing structures and curing them in place so they were just as effective as when "stoved." This required four years of intensive effort before an effective cure resulted. Effective research is another responsibility of the maintenance coating manufacturer.

Three Test Stages Required

Once an answer is obtained through research, it must be thoroughly time-tested. This may be done in two stages: (1) By panel tests in recognized severe environments and (2) By actually applying it in the field under field conditions to large plant areas.

Both tests are required to prove a material ready for presentation to industry. Panel tests come first and should be of two types:

1. Exposure to severe weathering corrosion, such as found at the International Nickel Test Station at Wrightsville Beach, North Carolina, or at the Battelle Memorial Institute's North Florida Test Station, Daytona Beach, Florida. At these places general weathering resistance is determined along with resistance to undercutting by salt air atmospheres. Chalking, checking, cracking, general appearance and other coating failures can be evaluated as well. Each of these qualities is important in a maintenance coating which may be continuously in the weather wherever it is used.

★ A paper presented under the title "Maintenance Coatings—Manufacturers' Responsibility" at a meeting of the Northeast Region, National Association of Corrosion Engineers, Huntington, W. Va., October 11-14, 1960.

2. The second type of test is the "in-plant" test under known exposure conditions. Such tests are made under a controlled set of exposures to quickly determine effectiveness of a coating for severe industrial exposures. Tests should include acid, alkaline and neutral exposures.

If panel tests prove satisfactory, then final proof is application under actual field conditions over reasonably large areas. Field application tests are extremely important to both the applicator and the purchaser because properties of the coating are determined under plant conditions. Wind, rain, cold, hot surfaces, humidity and other variables can be expected. Lap marks, overspray, sagging, pinholes and even cratering and "bug eyeing" caused by surface contamination, are application phenomena which may be encountered in a plant evaluation to a degree which they never would have been on laboratory panels. Coatings have been returned as often as

sponsibility occurred in making a recommendation to a hydrochloric acid plant which had been started up a month or so before a coating was applied and then was recoated again in a few weeks. The result: several structural members were penetrated by acid corrosion in six months.

The problem here not only involved selection of a coating of the proper type, but also application and surface preparation consideration as well. The solution was blasting, washing with clean water, brush blasting, flame treating the surface and applying a rapid-drying vinyl coating in several coats while the steel was hot and before inter-coat contamination could take place. Knowledge permitting solution of the customer's coating problems is a real part of the manufacturer's responsibility.

Application Is Real Key

It has been said that proper application is the key to an effective maintenance coating. This being the case,

knowledge of how a specialized coating should be applied is another of the coating manufacturer's responsibilities. Where special resins are used, catalysts may be required, solvents may be inflammable and possibly explosive under some conditions;

hot spray is sometimes required; certain thickness per coat may be a part of the specification; adhesion can be critical; force drying may be required for cure; or humidity and weather temperatures are important factors. The manufacturer must not only understand these factors but also must pass them on to the purchaser and train him or his applicator so the job can be done properly. The manufacturer is responsible for detailed and complete application specifications for his specialized coating. This includes on-the-job help if necessary.

The manufacturer must do all of these things to make sure that his customer gets the full value for his money and full protection for his plant for a sufficient length of time for specialized coatings to be economical.

Cooperation Is Essential

Often all of the efforts of the manufacturer are useless because of lack of understanding and interest on the part of the purchaser or applicator. To obtain the expected service from a maintenance coating, cooperation among the manufacturer, purchaser and applicator are required. The manufacturer must provide information about his product and its application. The purchaser's responsibility includes proper specifications for the coating and implementing them by effective and intelligent inspection.

The applicator, the key to coating effectiveness, has a heavy responsibility. He must study the product and its application specifications, conscientiously follow them and be as interested as either the manufacturer or the purchaser in doing a good and effective job.

• In 1959, 50,000 swimming pools were built in the United States. Only 17,000 of these were for use by clubs.

• About 72 brands of cleaning products for use in the home were on sale at USA supermarkets in 1959.

Responsibilities of High Performance Maintenance Coating Manufacturer*

C. G. Munger

Amercoat Corporation
South Gate, California

Abstract

Responsibilities of the maintenance coating manufacturer include a thorough knowledge of industrial corrosion conditions, proper laboratory and field testing, properly educating the user on his materials properties, method of handling and other details. He also has the responsibility for on-the-job assistance when requested.

1.7.3, 5.4.5, 5.3.2

ten times to the laboratory before passing this last test. This proof-testing is, then, another manufacturer's responsibility.

Proper Sale or Presentation Essential

After the coating has passed all panel-field tests, the manufacturer still has another responsibility: Proper presentation or sale to the customer. While many industrial maintenance coatings have a very broad range of properties and can solve many problems, none of them are universally applicable. The manufacturer must make an interesting presentation to the customer, but in so doing, must base his sales effort on a sound analysis of the problem before he can recommend a sound coating to solve the existing maintenance problem economically.

A good example of this type of re-

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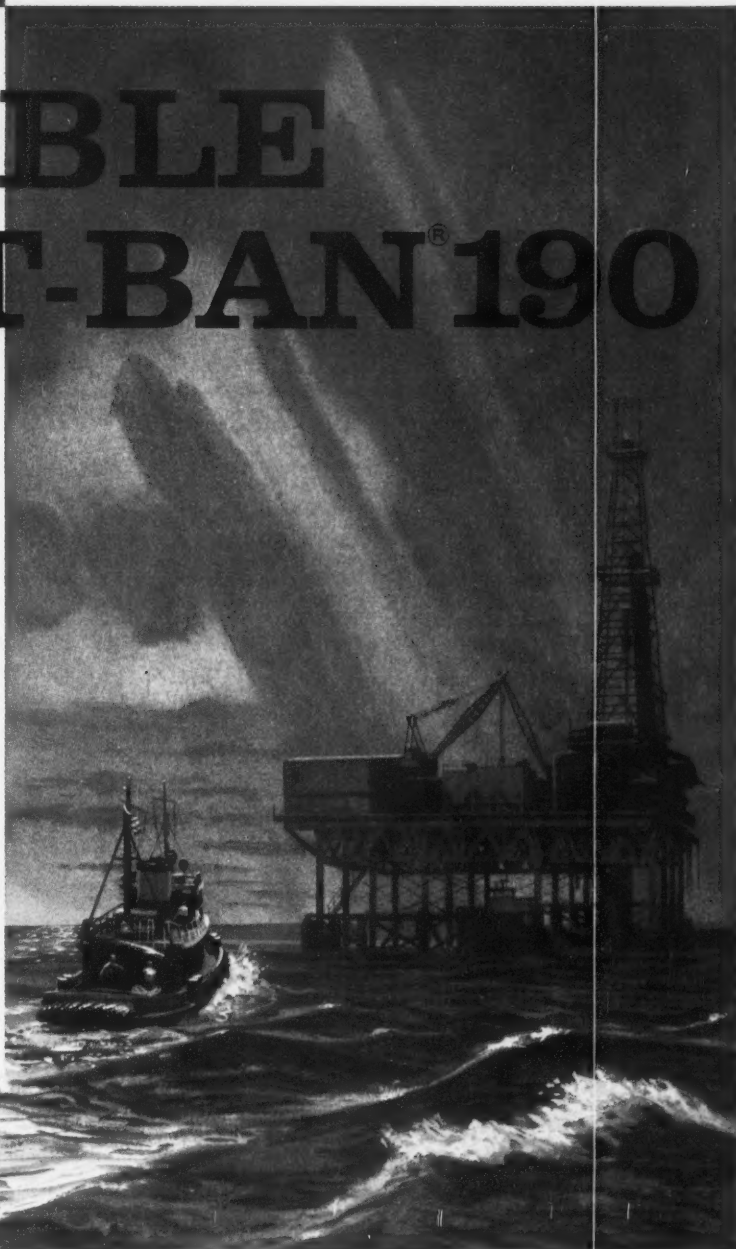
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Susceptibility of Epoxy Coatings To Damage by Fresh Water Immersion*

Harold Moroson
Newark College of Engineering
Newark, New Jersey

Abstract

Data are given on tests of epoxy coatings, resistance to submersion in fresh water with a variety of curing agents as the variable. Examples are given showing where formulations cured by amines failed. Naval Research Laboratory tests showed epoxy coatings blistered consistently. A hypothesis is offered on the mechanism by which the coatings fail and the mechanism of blistering.

S.4.5, 4.6.7

EPOXY RESINS are finding increasingly wide use as surface coatings in field applied systems for steel, concrete pipe, storage tanks, highways and waterways. Their properties of excellent chemical resistance and tight adhesion to various substrates have induced paint formulators to work hard and long to overcome their many drawbacks and difficulties. These are for example, the necessity of adding polyamine curing agents just prior to application, resulting in a limited pot-life or working life (between 1 and 8 hours), toxicity associated with these polyamines; relatively high cost; high viscosity and inherent brittleness of the fully cured resins which necessitates addition of flexibilizing agents.

Taken in balance, however, these deficiencies are outweighed by the advantage of obtaining chemical resistance equivalent to that of some baked coatings and the opportunity to formulate a 100 percent solids coating that has little or no shrinkage.

First satisfactory commercial use was for relatively small objects such as signs, hardware, and some process equipment. However, when considered for application involving prolonged fresh water immersions the resistance of epoxy resin based coatings is not outstanding.^{1,2,3} Formulations satisfactory in laboratory evaluations were found to be prone to blistering when subjected to water immersion when applied under field conditions of high humidity and/or low temperatures. Other failures ascribed to incomplete cure, such as loss of adhesion and softening, also were observed if coating application was carried out on a relatively wet day or if the ambient temperature fell below 50 F. While epoxy resin based paints are being suggested for large scale protection of concrete pipe, dams and waterways there

is some reason for caution in the light of recent developments.

Several Evaluations Made

The U. S. Army Engineer Waterways Experiment Station recently reported blistering of amine cured epoxy resin based coatings due to fresh water immersion. The conclusion reached is that: "to date all amine systems tried have blistered in less than a year when exposed to the coldest water and in 2 to 4 weeks in 120 F water."⁴

Of the approximately 135 epoxy resin coatings evaluated by the Rock Island Paint Laboratory, Corps of Engineers, Rock Island, Illinois, a large proportion of laboratory prepared paints and all proprietary coatings showed poor performance in water immersion, manifested by blisters, softening of the film and/or loss in adhesion.⁵

Curing agents employed were all of the room temperature curing types and included diethylene triamine, ethylene diamine, propylene diamine, amine adduct (excess polyamine reacted with epoxy resin), and polyamide resin (Versamid). No consistent variation in the failure pattern was observed to correlate with change in curing agent. All appeared prone to water sensitivity. This experience has been reported in the field in several other cases:

1. A cast concrete trunk sewer line in Jacksonville, Florida, was coated with two proprietary epoxy resin based paints applied in four coats to a total 12 mils. Only the inside of the line was coated in the field above ground, and after several days the coated pipe was placed into the ground, well below the water table. Within 2 to 4 weeks the epoxy coating developed blisters throughout the pipe, ranging in size from a fraction of an inch to several inches in diameter. Blistering appeared to be between coats rather than between concrete and the first coat.

2. Epoxy coatings on shot blasted steel surfaces of oil tankers show no significant breakdown after three years service and nothing to suggest failure is impending but the main defects have been local rusting and blistering in the film.⁶ This has not been fully explained, but local penetration of the film by water may be contributory.

3. A nine-boat concrete channel pier and navigation channel in the upper Mississippi coated with an epoxy resin based paint formulated by the Rock Island Corps of Engineers Paint Laboratory cured with polyamines and polyamides also blistered after prolonged water immersion.

Formulations were varied—liquid and solid epoxy resins were used, with and without flexibilizers, various filler loads, and different polyamines—all with the same result, i.e. blistering in water immersion.

Characteristics of Failures Described

Results of outdoor aging tests of epoxy resin based coatings show that film deterioration follows a pattern of loss of gloss, followed by checking,

blistering or peeling, but never by undercutting of the coating by rust or corrosion.⁸ Because it is well known that most plastics are sensitive to water by a diffusion mechanism it is possible water may act as a plasticizer and also be responsible for swelling.⁹

Effect of water on cured epoxy resins can be shown by measuring the flexural strength of strips of cast resin.⁷ In these tests, severe weakening of the resin was found to occur very rapidly during an initial period when water absorption was rapid. Constant load flexural deflection measurements on unreinforced strips of the most water resistant epoxy resins indicate that it is appreciably weakened by water although the effect is not as rapid or as great as for the polyester resins. It appears probable that there is a physical change with the water acting as a plasticizer or interval lubricant for movement of the large molecules.

A coating of epoxy resin-fiberglass reinforced pipe blistered in a short time when subjected to a static water pressure test of 200 to 300 psi. Therefore, no pipe manufacturers currently use epoxy resins in a gel or interior coating for epoxy pipe because of this sensitivity.¹

J. E. Cowling, Chief Coating Section, Naval Research Laboratory, found that because the Naval Laboratory recognizes the water sensitivity of epoxy resins it has not developed specifications for epoxy coatings to be used when water is a constituent of the environment. Blistering apparently has occurred consistently in epoxy coatings tested by the Naval Research Laboratory.

It is well known that, even when epoxy resin coatings are amine cured under laboratory conditions, they are much more sensitive to distilled than to tap water and will blister when immersed in distilled water. Other coatings, such as alkyls or vinyls are too hydrophobic to blister under similar conditions. A principal factor in this situation is the control required to achieve full cure, or cross linking, upon which development of ultimate physical and chemical properties depends.

In the laboratory, a paint film generally is applied at room temperature (75 F) and indoor heated room humidity (45 percent RH or less); in the field temperatures may be below 50 F and RH may be greater than 85 percent. The rate of cure or hardening is dependent upon temperature and humidity. Air drying time is 2 to 6 hours, but it takes some seven days to develop full chemical resistance at optimum temperatures and humidity. If temperatures are sufficiently low and the rate of cure is very slow, amine might evaporate to such an extent that full cure is never realized.

It is well known that high humidity causes the formation of "amine blush," as it is sometimes called. This is due to an amine carbonate whose formation from CO₂ in the air is catalyzed by high humidity. Amine blush gives the cured film a greasy, soapy feel and acts to prevent the amine from reacting with

* Submitted for publication August 26, 1960.

epoxy groups. A complete cure is prevented when amine available is reduced.

Mechanism of Blistering Described

Heavily filled epoxy resin coatings containing solvent tend to lose it from the surface initially, and consequently cure from the outside surface first. Cure progresses slowly to the interior of the film and, if the substrate is damp, the bottom cure will be retarded still further.

An investigation carried out by the author indicates that the cause of blistering is incomplete cure of the resin, which is softened by water causing bubbles to be formed by surface tension forces.

If the coating is subjected to water immersion before curing is complete small blisters usually result. These blisters are rather soft at this stage, appear at random and some of them will increase in size. Water has the ability to swell all plastics and to cause osmotic type blisters when the ion concentration in the plastic is greater than in the water surrounding the plastic.

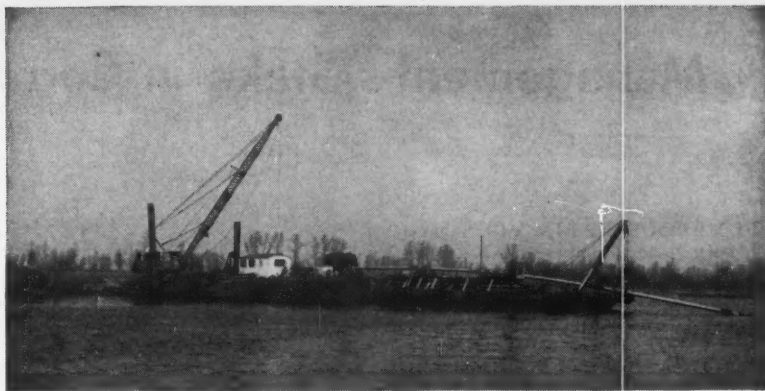
If a blister is punctured at this stage, water may be found inside. Apparently, the soft, undercured bottom layer of coating allows permeation of water which collects when it is unable to penetrate further. The curing reaction continues, though slowed down by the water, so that eventually the blisters harden to a toughness comparable to adjacent unblistered areas. A possible remedy for blistering is to make the epoxy resin coating less polar (and less hydrophilic) either by using longer chain alkyl amines, or by incorporating hydrophobic diluents such as coal tar pitch or asphalt. However, this has the undesirable feature of decreasing chemical resistance of the coating and lowering the softening point.

Summary

Epoxy coatings for concrete and steel intended for water immersion or exposure are susceptible to blistering after one week to one year. This phenomenon is apparently independent of formulation and method of application but depends on conditions of humidity and temperature during application of the coating and is related to an incomplete cure of the epoxy resin. Blisters are not sites for further attack by water and oxygen and seem to harden with age.

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8. Private communication, Dr. Walter Brenner, New York University.
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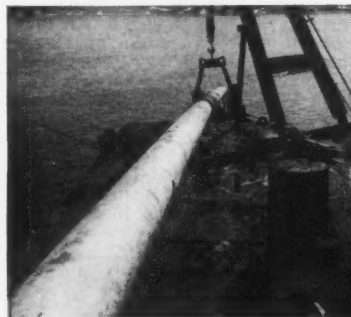


The three barges at work in mid-river

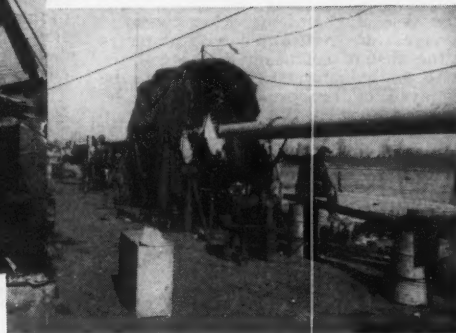
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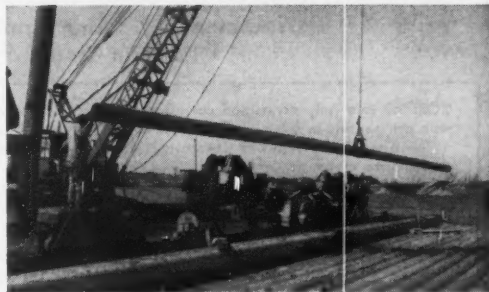


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Management's Stake in Corrosion Control*

NUMEROUS ESTIMATES have been made of annual costs of corrosion on international, national and industry bases. While everyone is impressed with the magnitude of the figures cited in such estimates, they do not always have the impact that might naturally be expected. The reference here to impact is in relation to the action that might reasonably be expected to follow such realization of the tremendous costs of corrosion and the savings that should result from steps taken to reduce such losses. These statistics have not led to action by industry in general or individual companies to the extent that might reasonably follow from the facts that are cited.

A possible reason for this anomalous situation may be found in the very magnitude of the figures. Perhaps, we have become resigned to being not able to do much about anything estimated in the billions. Perhaps, by reaching such proportions, losses due to corrosion have gotten into the same category as taxes, which, like death, are considered to be inevitable. Even so, management does exhibit a proper concern for taxes and does what it can to reduce this burden on a company basis even when the tax bill as a whole would seem to be so overwhelming as to defy efforts to reduce it.

So, it is suggested that when company managers are confronted with statistics re the cost of corrosion to the country or to an industry, they should not be dismayed by the problem as a whole,

★ An address given at the Corporate Member Luncheon during the 17th Annual Conference, National Association of Corrosion Engineers, March 13-17, 1961, Buffalo, N. Y.

F. L. LaQue

*International Nickel Company, Inc.
New York, New York*

but seek to find ways to reduce each company's share of the total. The fact that such action in many quarters will reduce the total is of less consequence than that each company benefits from activities that it undertakes individually or supports by way of joint action with others.

The chance of success in the control of corrosion is much greater than for control of taxes. Taxes can be affected only in some remote way involving a number of diffuse factors usually beyond individual influence and without much chance or hope for localized benefit.

On the other hand, even though corrosion problems cost so much in the aggregate, they are all very specific where they occur. They involve natural forces that are becoming understood better and are capable of effective and on the spot control.

This control requires the services of experts capable of applying technical knowledge to the solution of specific problems. These experts are the corrosion engineers and the professional society in which their accumulated knowledge resides is the NACE.

Management being addressed on this occasion is divided into two general classes. The first includes management of companies who are concerned with control of corrosion that is a nuisance

to them and is costing them money. 53% of the Corporate members are in this category. The second includes management of companies who are in the business of selling some means of controlling corrosion at a profit and who, therefore, view corrosion in quite a different light from those in class one. 47% of the Corporate members are in this category. Both classes of management have, or should have, at least one thing in common. To be successful in their approaches to the control of corrosion so as to reduce a loss or create a profit, they must proceed on a sound basis and take advantage of the most up to date knowledge of what they are dealing with. This is where the NACE enters the picture.

NACE provides the best channel of communication between people who have corrosion problems to be solved and people who have found solutions for them. This exchange of knowledge flows in two principal channels. The first is between companies in the same or even different industries who have developed knowledge of means of corrosion control that they are willing to share with others or who are willing to engage with others in a cooperative effort to deal with a common problem. The second principal channel of communication is between people with problems and people who are exploiting ways of dealing with them.

NACE can in a very real sense be characterized as playing a vital role in the processes of communication that are essential to achieving the different objectives of the two classes of management previously referred to.

The necessary communication is provided by the NACE in several ways:

1. Through the activities of many technical committees organized to assemble, review, qualify and publish data useful in dealing with specific corrosion problems or means for their control. There are currently nine main Technical Practices Committees and over 160 sub-committees dealing with special topics within the scopes of the main committees.

2. Presentation of papers at national, regional and local sectional meetings.

3. Publication of technical papers in CORROSION magazine.

4. Publication of abstracts of papers on corrosion gleaned from many sources and on an international basis.

5. Preparation and distribution of corrosion abstracts.

6. Publication of annual bibliographies of corrosion literature.

7. Publication of special committee reports.

It seems reasonable to assume that management will recognize that these activities are valuable and probably essential to progress in means of achieving better and more economical control of corrosion. They also will admit that no one company could establish an equivalent scheme of communication by its own effort or could afford to do this

(Continued on Page 32)

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**WHERE RESEARCH TODAY
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Management's Stake—

(Continued From Page 30)

even if it were possible. From this, it follows that management must take whatever action is necessary to insure that the recognized valuable functions of the NACE are continued at an adequate level of quantity and quality of effort. This means finally that NACE must have sufficient income to support its necessary activities.

While many of the activities of the NACE are self sustaining, or almost so, others must be operated at a loss.

Since it is necessary to encourage participation in NACE activities by as many as possible of the competent corrosion engineers in the country and to attract to membership the young engineers who will eventually have to carry on the work, it is necessary to keep the dues for ordinary membership as low as possible. In 1960 the total dues from ordinary members amounted to about \$41,000 out of a total budget of over \$400,000. Stated another way, the total expense per ordinary member was about \$67 as compared with annual dues per member of \$15. The difference was made up from income from advertising, sales of publications, sales of space at the annual exhibition and dues from Corporate Members. The latter accounted for about \$8 of the gap between the \$15 income and the \$67 expense per ordinary member. While this may not appear to represent a major factor in the accounting, it usually represents the difference between an operation in the black and an operation in the red. It is obviously essential to operate in the black most of the time in order to provide reserves for future contingencies.

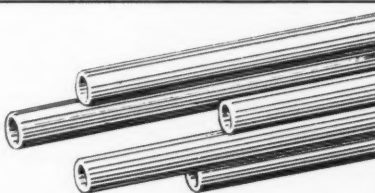
To complete the picture, the total revenue is divided in the following rough proportions:

Source of Income	Percent of Total
Dues from ordinary members....	21
Dues from corporate members....	11
Income from advertising.....	31
Income from sales of publications..	14
Income from investments.....	2
Income from exhibits.....	20
Miscellaneous sources.....	1
	100

It is evident from these figures that Corporate Members who get the greatest financial benefit from the activities of NACE are not called upon to contribute unduly to the support of NACE's work. As a matter of fact, it might be argued that Corporate Members enjoy a multiplying factor of nearly ten in terms of what their corporate dues purchase by way of activity of direct benefit to them.

It is true that all Corporate Members do not benefit equally from the work of NACE. But any Corporate Member has within his grasp the means of correcting such situations. The best way to insure maximum return from support of the NACE is to exert appropriate influence on the nature and extent of NACE's programs. This can be done by encouraging or even requiring delegated representatives and other employees who are ordinary members to participate actively in NACE affairs, and particularly in the work of the many technical committees and sub-committees. It is possible in this way to insure that a proper proportion of NACE activity is in an area of direct interest to any Corporate Member.

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If your installation requires high temperature protection from sulfur-bearing gases, carburizing atmospheres, exposure to H₂S, SO₂ and many other corrosive environments, you need more than a surface aluminum coating.

ALONizing offers aluminum impregnation with diffusion penetration depths up to .035". By alloying with the steel, the aluminum becomes an integral part of the base metal and therefore cannot peel, chip, crack or run off.

This duplex structure of base steel and aluminum rich alloy exterior is the best assurance of corrosion and oxidation resistance, even beyond 1600°F-years of service at a fraction of the cost of chrome-nickel alloys.

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PITTSBURGH 38, PA.

Pulp Digester Corrosion Control

Four articles on corrosion control problems in pulp digesters are scheduled for publication in the June issue Technical Topics.

Corrosion Resistance of Stainless Overlay on Kraft Digester—Weyerhaeuser's Experience, by C. L. Carns

Calcium Sulfate Scale Responsible for Corrosion of Stainless Steel Pulp Digesters, by W. M. Scott

Review of Some Data on Corrosion of Stainless Steel and Higher Alloys in Pulp Mill Equipment, by Harold C. Templeton

Cathodic Protection Proposed for Vapor Area in Pulp Digester, by L. C. Wasson

It can be argued, also, that industry as a whole can benefit from NACE work without contributing to its support. This could be the case for a limited period, but since dues from Corporate Members frequently represent the extent of any excess of income over expenses, any falling off of revenue from this source would sooner or later lead to either total failure of the NACE or a drastic reduction in the scope and quality of those services from which corporations are the principal beneficiaries.

Corporate membership dues can be considered, therefore, as a sort of insurance premium at a reasonable rate in terms of the value of what is insured. There are usually, also, annual dividends which are likely to be greatly in excess of the annual premiums (dues) as the work of the NACE leads to reductions in losses or increases in profits amounting to many times the dues paid.

If the NACE didn't exist, it either would have to be created or some other action at much greater expense would have to be taken by individual corporations or groups of them as a substitute for the means provided by the NACE as it now exists.

It is submitted that Corporate membership in the NACE is a sound investment that present Corporate Members should bring to the attention of other corporations in their industry areas. This would insure an equitable sharing of the load, as well as of the benefits and permit the NACE to be even more valuable to industry through increases in the magnitude and quality of its efforts made possible by a higher level of income to support such expanded activities.

NACE's 18th Annual Conference and 1962 Corrosion Show will be held at the Municipal Auditorium, Kansas City, Mo., March 19-23, 1962.

The 1961 South Central Region Conference and Exhibition will be October 24-27, Shamrock-Hilton Hotel, Houston, Texas.

The 1961 Northeast Region Conference will be Oct. 20-Nov. 2 at the Hotel Statler, New York City.

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RECORD and REPORT



Plastic Coated Valves Resist Two-Year Refinery Exposures

Plastic coated valves have been in service for over two years in some process units and acid restoring units of Humble Oil & Refining Company's Bayway Refinery of the Esso Standard Division at Linden, N.J. Coated with chlorinated polyether, the lubricated plug steel valves have successfully handled (1) 45 percent sulfuric acid at 110 F, (2) 45 to 78 percent sulfuric acid for blending at 130 to 140 F, (3) spent butanes with 65 percent mechanically entrained sulfuric acid, (4) ethane with mechanically entrained traces of hydrochloric acid and (5) 43 to 53 percent spent sulfuric acid.

The high cost of valve replacements resulting from corrosion damage has caused the process industries to watch case history performance data on plastic coating equipment as a possible economic answer to the problem. For example, stainless steel valves which were replaced at the Bayway Refinery by plastic coated valves cost two and a half times as much as coated valves and were expected to give about 1½ years' service. Many of the plastic coated valves first installed at the Bayway are still in serviceable condition after more than two years' operation.

Valve Coating Requirements

To be economical for a wide range of process plant applications, a valve coating should have three characteristics, according to Rockwell Manufacturing Co., 400 North Lexington Ave., Pittsburgh, Pa., whose valves were coated with a chlorinated polyether called Penton, made by Hercules Powder Co., Wilmington, Del. These three characteristics are as follows:

1. Easy application: A coating must properly cover irregular shapes as found in valves. This coverage must be accomplished inexpensively or the economic advantage over special metal valves would be lost.

2. Wide range of applications: The market for a coated valve must be large enough to allow manufacturing economics.

3. Long service life: Too frequent replacement would offset the economic advantage of low initial cost over more expensive special metal valves. To give

long service life, a valve coating must have good surface adhesion, abrasion resistance, resilient structure and resistance to cyclic wear.

In checking various plastics to fulfill these characteristics, Rockwell engineers found phenolics too brittle to perform under routine plant handling. Epoxies did not resist cyclic valve operations. Polyvinyl chloride had a high temperature resistance of 140 F but poor wear resistance. Polyfluorohydrocarbons were too difficult to apply to valves, thus raising their cost.

Whirlclad Application Process

Rockwell Manufacturing found that Penton could be applied by a modified fluidized bed process called Whirlclad at reasonable cost to give chemical and physical resistance as required. A patented process of the Polymer Corporation, Reading, Pa., the Whirlclad system for applying Penton coatings involves preheating of the part to be coated to about 500 F, a 25-second dip into a fluidized bed of finely divided Penton powder and a final bake of the part in a gas fired oven at 450 F.

The 25-second dip gives a 2 to 2.5 mils thickness on internal and external surfaces of the valve.

Little surface preparation of the valve surfaces is required other than routine cleaning. It is necessary, however, to "radius" all sharp edges because the coating tends to be thin on sharp edges.

A static voltage test is used to detect porosity in the coating. This can be done by immersing the valve plug slowly in an electrolytic bath or by probing the more complex shapes such as the valve body with an electrode. In

PLASTIC COATED valve on a refinery painerforme unit has given good resistance to ethane with traces of dilute hydrochloric acid at 160 F. This four-inch Rockwell-Nordstrom lubricated plug valve on an overhead vent line of T-2 tamer was coated with Penton, a chlorinated polyether made by Hercules Powder Company, Wilmington, Del.

either case, a current reading would indicate the presence of a pinhole that permitted the electrical current to flow through the coating.

In coating the Rockwell-Nordstrom standard plug valve, no design problems were encountered. The plug does not bear against the coating. As in most standard lubricated plug valves, the plug's only contact is with the lubricant, thus reducing friction and wear to a minimum.

About 3000 Penton coated valves are in service. About one percent of these have been returned because of some failure. Most failures resulted from physical damage to the coating caused by abrasive material in the line fluid, use of the valve for throttling or a combination of these two.

For example, line fluid in one installation was a mixture of chemicals highly corrosive to carbon steel pipes. This pipe corrosion created a fine abrasive powder which was carried by the line fluid into the valve where it abraded away sufficient coating to eliminate virtually all protection to the valve.

Other causes of failure resulted from using the valve for throttling. The changed flow pattern caused cavitation in the coating, allowing the base metal to be attacked by the corrosive line fluid. The coating thus became loosened by undercutting.

Italian Metallurgy Meeting

The fifth meeting of the Italian Association on Metallurgy's Centro Leghe Leggere will be held October 7-9 in Milan. Topic of the meeting will be "Surface Treatments of Aluminum."

Persons wishing to attend should contact the Secretary of the Associazione Italiana di Metallurgia, Via della Moscova 16, Milan, Italy.

BOOK NEWS

The Fermi Surface. W. A. Harrison and M. B. Webb, editors. 356 pages, 8½ x 11. Cloth. 1960. John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y. Per copy, \$10.

Consists of 33 technical papers and discussions presented at an International Conference on The Fermi Surface held at Cooperstown, N. Y. August 22-24, 1960. The conference was sponsored by the U.S. Air Force Office of Scientific Research and the General Electric Research Laboratory.

Persons who are concerned with studies of the electrical properties of matter, especially metals, probably will find substantial information on the present state of thinking of those who are in the field. Physical chemists, metallurgists, mathematicians and others involved in research involving these ultimate properties can estimate the nature of the material, which includes sections on theory, De-Haas-Van Alphen Effect, Galvanomagnetic Effects, Cyclotron Resonance, Anomalous Skin Effect, Magnetoacoustic Effect, Transport Properties and Studies of Alloys. The papers and discussions are summarized in the last two articles in the book.

There is a list of authors and a subject index. Illustrations are numerous and the individual papers are fully referenced.

Rare Earth Elements—Extraction, Analysis, Applications. (Redkoze-mel'nye elementy—poluchenie, analiz, primeneniye) 1960. Office of Technical Services, U.S. Dept. of Commerce, Wash., D. C. Per copy, \$3.75.

A translation from Russian by the Israel Program for Scientific Translations. Published in Israel for the National Science Foundation, Washington D. C. Forty-two articles substantially covering current Russian thinking about the rare earth of elements. Topics include utilization, methods of production, production of pure cerium, separation of the elements of the yttrium sub-group, large-scale chromatographic separation of rare-earth elements and sub-groups, anion exchange separation, x-ray spectroscopic analysis, spectrophotometric studies, use of rare-earth elements as catalysts and others.

Because of the rapidly developing uses of these minerals for various purposes connected with development of corrosion-resistant metals and mixtures of metals and ceramics and organics, the data may be interesting.

There are many illustrations and graphed data, tables and each article is referenced.

Summary of the Conference on Pitting Corrosion (Bericht Über die Diskussionstagung Lochfrasskorrosion). (In German.) H. J. Engell and W. Katz, editors. 1960. Verlag Chemie, GMBH, Weinheim/Bergstr., Germany. Per copy, DM 26.

Proceedings of the sessions held Febru-

ary 19-20, 1959 in Dusseldorf under the auspices of Deutsche Gesellschaft für Metallkunde and Verein Deutscher Eisenhüttenleute. Fifteen papers and related discussions are presented. There are numerous graphed data and tabulated information. Each paper is referenced.

Subject matter includes consideration of passivity, pitting of shipbuilding steel, boilers, tankships, copper and nickel, zinc, lead, aluminum and aluminum alloys.

Metal Cleaning Bibliographical Abstracts, 1960 Supplement. Prepared by Jay C. Harris. 34 pages, 6 x 9 inches, paper. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. Per copy \$2.

A collection of abstracts principally covering years 1957-60 with additional abstracts for 1951-56. Abstracts are arranged numerically keyed to a subject index.

A check against a roughly equivalent classification in the NACE Abstract Filing Index indicates that perhaps these abstracts are of articles wholly, or substantially about metal cleaning, and do not include those in which the subject is incidental to another theme. A majority of the abstracts seem to have been taken from CHEMICAL ABSTRACTS.

Applied Radiation and Radioisotope Test Methods, a symposium. 112 pages, 6 x 9 inches, hard paper back. 1960. American Society for Testing Materials, 1916 Race St., Philadelphia, Pa. Per copy \$3.75.

Consisting of eleven technical papers presented at the Symposium on Applied Radiation and Radioisotope Test Methods in San Francisco, October 13, 1959. The papers concern ring wear testing in Diesel engines, grain boundary segregation studies, measurement of moisture in soils, analysis of sulfur in hydrocarbons, determining uniformity of mixing, and others.

1961 Directory. Governmental Air Pollution Agencies. 42 pages 4 x 8½ inches. Air Pollution Control Assoc., 4400 Fifth Ave., Pittsburgh 13, Pa. Free.

Names and addresses of governmental air pollution control agencies and their principal officers in the United States and Canada.

Report of the Activities of Commission No. 4 on Protection Against Corrosion 1959: Technical Report II. (In French) 65 pages, 8½ x 11, typescript, plus charts, paper cover. April, 1960. Belgian Association for the Study and Use of Materials, Secretariat, 38 rue de Naples, Brussels 5, Belgium. Availability not indicated.

One of the series of technical reports of the Belgian committee working on corrosion protection. Contents include: Outline of work performed, climatic tables, characteristics of experimental stations;

Year 1952, study of 67 anti-corrosion paints; 1954, comparative studies on surface preparation and the use of rust inhibitors and wash primers.

Year 1955, comparison of epoxy and alkyd base paints and finishing paints; 1959, study of the influence of surface heterogeneities and application methods on paint behavior; study of atmospheric corrosion of structural steels.

POSITIONS WANTED and AVAILABLE

Active and Junior NACE members and companies seeking salaried employees may run two consecutive advertisements annually without charge under this heading, not over

35 words set in 8 point type. Advertisements to other specifications will be charged for at \$12.50 a column inch.

Positions Wanted

Sales Engineer—25 years' experience in design, construction, maintenance, corrosion and supervision in refinery and chemical manufacturing. Desire position in technical sales or service. E. E. Degree. Resume on request. Prefer West or Midwest. CORROSION, Box 61-12

Sales Engineer—Experienced in analyzing corrosion problems, sales of protective coatings & linings, application or installation of materials. Desire sales or service position in corrosion control work. Resume on request. Willing to relocate. CORROSION, Box 61-2

Corrosion-Materials-Finishing Engineer—Broad experience-background covering laboratory, technical sales/service in above lines. Heavy supervision and management responsibilities, in manufacturing as well as laboratory. Last 5 years in missile field. Resume on request. CORROSION, 61-6.

Sales, Cathodic Protection—Experienced in sale of cathodic protection rectifiers; desire sales position with cathodic protection group or manufacturers sales force. Resume on request. Willing to relocate. CORROSION, Box 61-11

CORROSION ENGINEER—Bachelor's degrees chemistry, chemical engineering; graduate credits metallurgy. Sixteen years government, industry associated with R & D groups on corrosion problems, materials testing, process development. Currently chemical plant consultant. North East location. CORROSION, Box 61-8.

Positions Available

Prominent Manufacturer of welded stainless and alloy tubing and pipe desires experienced sales representative in Southeast, to be located in the vicinity of Atlanta. Free to travel. Good opportunity for qualified person. Please write CORROSION, 61-5.

Chemical Engineer—Knowledge of current water treating practices by top flight, growing water treating company. Man selected will have outgoing personality and administrative ability for future advance. Excellent salary, moving expenses, insurance. Send resume and desired salary. Our employees know of this advertisement. CORROSION, 61-7.

MEDIUM SIZE aggressive service company seeking researcher for development work on chemicals used in petroleum production. Experience in corrosion inhibitors, scale inhibitors, demulsifiers, etc. Knowledge of petroleum production required. Salary open. Send resume to CORROSION, Box 61-10.

TWO CORROSION ENGINEERS required by Midwest consulting firm. Graduate electrical or metallurgical-chemical engineers experienced in field and design corrosion engineering. Send resume including personal data and experience, registration status, salary desired, willingness to travel. CORROSION, Box 61-9.



Even strong acid can't etch concrete floor coated with NEW GLID-CRETE

Floors "floored" by acids and chemicals? Here's the answer . . .

New GLID-CRETE, based on a catalyzed epoxy resin, used to patch or resurface concrete floors was given the acid test. A 50% solution of hydrochloric acid was poured on bare concrete and on concrete topped with $\frac{1}{8}$ " of GLID-CRETE. The concrete was badly etched.

GLID-CRETE was unharmed—and will stay that way!

Easy to apply, GLID-CRETE is six times more abrasion and impact resistant than concrete. It offers many outstanding advantages in the maintenance, repair and construction of masonry floors and structures.

GLID-CRETE can save you money. Time too. Write today for complete information.



MAINTENANCE FINISHES DIVISION

The Glidden Company
900 Union Commerce Building
Cleveland 14, Ohio

In Canada: The Glidden Company, Ltd., Toronto, Ontario

Ratio Changes Made Easily on Epoxy Proportioning Unit

A unit for proportioning, dispensing and mixing multi-component reactive resins such as epoxies and polyurethanes has been redesigned so that proportioning ratios can be changed without substituting sprockets or gears.

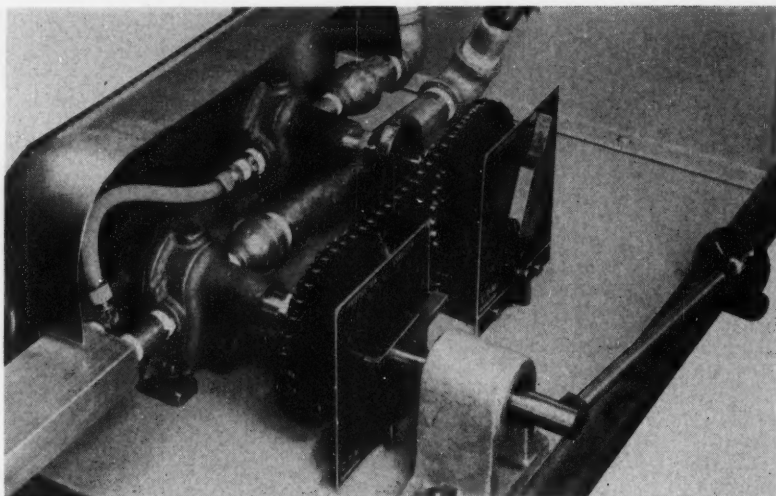
The new unit has been designed to give proportional accuracy of the two-component media dispensed through mechanical linkage operating positive displacement pumps. Ratio changes are made by simple adjustment of an arm on a calibrated dial. Ratio settings can be made from 1:1 to 100:1 with adjustment between these two extremes.

Called the Multi-Rez-Processor and manufactured by CPM Special Machinery Corp., 324 Butler St., Brooklyn 17, N. Y., the unit is designed to dispense an adjustable predetermined volume of the two components in Proportion. Blending of the resin mix is done by a motorized mixer with a plastic impeller. Short pot-life resin mixes can be handled, according to Special Machinery.

The unit is shipped completely assembled with reservoirs and dispenser.

The 1961 Northeast Region Conference will be Oct. 20-Nov. 2 at the Hotel Statler, New York City.

Greater Boston Section will hold a corrosion short course June 20-21 at the Wentworth Institute, Boston, Mass.



PROPORTIONAL DISPENSING of two-component reactive resins can be made by a simple adjustment of an arm on a calibrated dial. Ratio changes can be made from 1:1 to 100:1 with adjustments between these two extremes. The Proportion-Variator is part of a unit called Multi-Rez-Processor for proportioning, dispensing and mixing multi-component reactive resins. The unit is manufactured by CPM Special Machinery Corp., 324 Butler St., Brooklyn 17, N. Y.

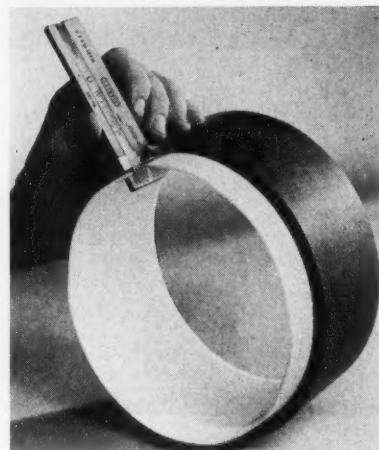
Chemical Resistant Tubing Has Bonded Inner Plastic Lining

A new chemical resistant tubing composed of a plastic inner lining bonded within a sleeve of Micarta laminate is being manufactured to handle corrosive liquids. This tubing also is designed for use as bearings or bushings and in materials handling applications which require tubing whose inner surface has low coefficient of friction or extreme resistance to corrosive action.

In such applications, the laminate and plastic materials have good dielectric properties. The plastic inner liner made of Teflon offers self lubrication and chemical resistance; the Micarta outer shell provides physical strength.

Called HY-380 tubing, it can be produced with internal diameters from 2 to 12 inches with wall thicknesses from $\frac{1}{8}$ to 1 inch. Maximum length is about two feet.

The new tubing is manufactured by Westinghouse Electric Corporation's Micarta Division, Hampton, S.C.



PLASTIC LINING bonded inside a Micarta laminate sleeve is basis of a new chemical resistant tubing produced by Westinghouse Electric Corporation's Micarta Division, Hampton, S.C. The plastic lining is made of Teflon.

Strange Low Temperature Reaction Experienced

An interesting phenomenon was observed at the National Bureau of Standards during recent free radicals research conducted for the Department of Defense. In experiments at the bureau's corrosion laboratory, no reaction occurred when oxygen was deposited at a temperature of 4 K on the surface of a copper specimen. But when the oxygen was partially dissociated by passage through a high frequency microwave discharge before a similar deposition, a thin film formed that remained solid at room temperature.

These results, which are of particular significance to NBS work on fundamen-

tal mechanisms of corrosion, will be the basis for further research on other metals and gases.

In recent years, investigations have been conducted on short-lived reactive species first formed in an electric discharge and then trapped and stored on a low temperature surface. However, little data is available on reactions occurring between oxygen and a metal surface at very low temperatures. The present work was begun to complement the bureau's free radicals program. Copper was chosen as the metal surface to be studied because of its known chemical properties.

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Correspondence Course Available on Corrosion

A 15-lesson home study correspondence course on corrosion is now available through the education division of the American Society for Metals, Nov-eltz 3, Ohio. The course, written by Prof. Mars G. Fontana, head of the metallurgical engineering department of Ohio State University, covers subjects from atmospheric corrosion to acid media and high temperature environments.

Lesson 2 of the course, for example, opens with a discussion of electromotive force and the galvanic series, then proceeds to passivity, metallurgical factors, including grain boundaries, impurities and alloys. The section dealing with equilibria or constitution diagrams explains their construction and use and has several diagrams illustrating points in the text.

Corrosion of iron and steel covers types and various characteristics of cast irons.

Australian Corrosion Group Changes Association Name

At the recent First Federal Conference of the Australian Association for Corrosion Prevention, the association shortened its name to Australasian Corrosion Association and extended its activities to include New Zealand.

The new association—an amalgamation of AACP and the New Zealand Corrosion Association—has branches in Victoria, New South Wales, Queensland and New Zealand. Branches are proposed for South Australia and Western Australia.

The change in name also was desirable to indicate more clearly the increasing efforts of the association in corrosion study and the collection, coordination and distribution of corrosion knowledge.

PERIODICALS

Environmental Effects on Materials and Equipment. Vol. 1, No. 1, January, 1961. 36 pages, 7 x 9 3/4 inches, type-script. Published by Prevention of Deterioration Center, National Academy of Sciences, National Research Council, 2101 Constitution Ave., Washington 25, D.C. Subscription, per year \$25.

An abstracts journal intended for design engineers, materials scientists, specifications writers and evaluators, test personnel, research directors and others concerned with reliability, operability and durability of military and other material in all environmental conditions of transportation storage and use. Emphasized field is "space-associated" environment.

Scheduled to include at least 40 abstracts monthly and forty or more telegraphic or key word abstracts of current articles from world's scientific literature. Each issue has subject and author indexes. A cumulative annual index will be provided.

American consumers purchased five million television sets, half a million dish washers and 400 billion cigarettes last year.

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KEEPS METAL SURFACES FREE FROM RUST



There's a job for Valvoline Tectyl in your industry, protecting metal surfaces against rust and corrosion during shipping and storage.

Low-cost Tectyl rust preventives are widely used by the military services and by industry.

Tectyl's easy-to-apply, easy-to-remove film provides complete protection from the effects of snow, rain, perspiration, humidity, salt air, and corrosive fumes.

There is a Tectyl product for every need, with more than 40 variations of three principal types: oil-type, solvent cut-back and hot dip. Brush on, spray on or immerse. We suggest you write today for your copies of two helpful, detailed Tectyl charts which give industrial and government specifications and applications.

VALVOLINE

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RUST PREVENTIVES

VALVOLINE OIL COMPANY
Division of Ashland Oil & Refining Company
Piquette, Pennsylvania • Main Office • Ashland, Kentucky



CORROSION RESISTANCE from a variety of agricultural chemicals has been achieved by a vinyl-urethane coating system on this Grumman Ag-Cat, specifically designed for crop dusting and spraying operations at crop-top altitudes.

Vinyl-Urethane Coating System Used on Crop Spraying Airplane

A vinyl-urethane coating system has been evaluated as a protective finish for the Grumman Ag-Cat, a two-wing airplane specifically designed for aerial application of agricultural chemicals.

The coating was designed to solve unusual corrosion problems on these airplanes. Metal and other materials used in the construction of the planes must be protected against a variety of corrosive dusts and liquid chemicals that are sprayed from special outlets along the bi-plane's lower wing. Spray-back from these nozzles exposes the plane's surface to water and oil solutions containing chlorinated organic chemicals, ammonia, emulsifiers and metal salts.

Further corrosion complications are created by temperature extremes. Some parts of the plane, especially those near the engine, experience high temperatures.

Produced by Carroll Products, Inc., Farmingdale, N.Y., the vinyl-urethane coatings are supplied as two-part solvent systems. One part contains polyisocyanate; the other modified vinyl chloride-acetate copolymer produced by Union Carbide Plastics Co. and designated as Bakelite VAGH.

The hydroxyl groups introduced into the vinyl during synthesis provide reactive points for cross-linking through the isocyanate molecules, thereby converting the normally thermoplastic vinyl resin to a thermosetting material. The chemical and weather resistant properties of the vinyl are retained and improved because the cross-linked structure reduces the solubility of the resin and increases its heat stability. High gloss finishes are possible with this formulation, according to Carroll Products.

Pot life of the mixed coating system is about eight hours. The coating can be applied by brush, spray, dip or roller.

These coatings also are used in other high stress applications such as chemical processing equipment, tanker lin-

ings, boat decks and laboratory furniture. Application can be made on wood and metal.

Eleven Corrosion Papers To Be on Achema Program

Eleven papers on corrosion will be given at the symposium on "Physical and Chemical Durability of Structural Materials in Chemical Engineering" as part of the June 9-17 European Convention of Chemical Engineering at Frankfurt, Germany.

This symposium will be the 15th meeting sponsored by the European Federation of Corrosion. Additional information can be obtained by writing Dechema, Frankfurt (Main) 7, Postfach 7746, Germany.

International Galvanizing Conference to Be June 4-9

The Sixth International Galvanizing Conference will be held June 4-9 at Interlaken, Switzerland. One of the conference's nine sessions will be devoted to corrosion.

A total of 23 technical papers presented by galvanizing personnel from Canada, Australia, the United States and Eastern Europe will be given.

A new feature of the meeting will be three sessions on management: labor management and welfare, plant layout and costing and financial management.

Plastics in Packaging

"Plastics in Packaging" will be the theme of the June 14 conference sponsored by the Quebec Section of the Society of Plastics Engineers at the Sheraton Mount Royal Hotel. The technical program will include ten papers on such subjects as blow molding and its future applications in packaging, polypropylene film, foam products and skin packaging.

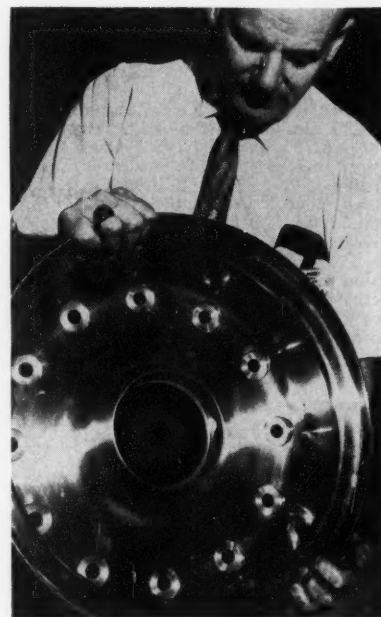
Titanium Used for Corrosion Resistant Aircraft Wheels

A corrosion resistant aircraft wheel made of titanium that will withstand more than 1000 degrees of heat has been built by Goodyear Tire & Rubber Co., Akron 16, Ohio.

The titanium wheel has several safety measures, the major one being corrosion resistance, according to Goodyear. The wheel is designed for use on jets and propeller driven aircraft. High temperature and corrosion resistance are inherent properties of titanium.

The wheel also is lighter and leaves more space for brakes because of thinner sections than on wheels made of magnesium and aluminum alloys, Goodyear explains. Titanium wheels have good flexibility and are able to withstand greater impact loads without failure.

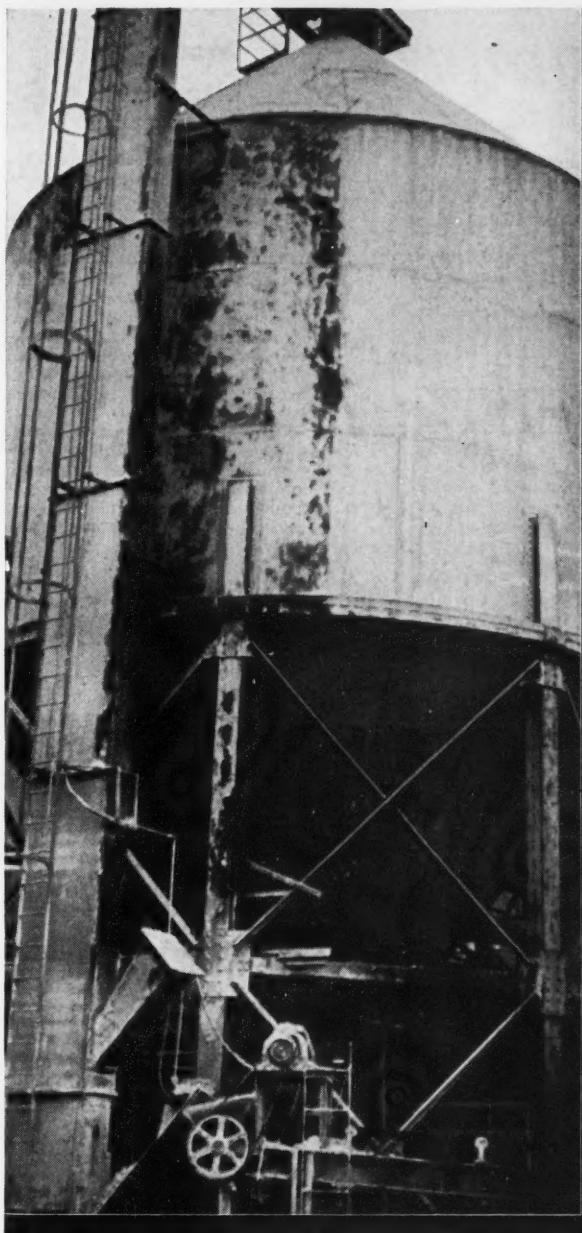
Because titanium conducts heat at a low rate, the new wheel allows tires to remain cooler; less heat is transmitted to them from the brakes.



AIRCRAFT WHEELS made of titanium are being fabricated to take advantage of the metals inherent characteristics of high temperature and corrosion resistance plus light weight derived from good strength-weight ratios. The wheel has been designed for use on jet and propeller driven aircraft, both commercial and military. The new wheel is built by Goodyear Tire & Rubber Co., Akron, Ohio.

Powder Metallurgy Meeting

The 4th International Powder Metallurgy Congress will be held in Reutte, Tyrol, Austria, June 20-24. A large delegation from the United States will be among the 37 participating nations. Topic for the congress will be "Powder Metallurgy in the Nuclear Age."



Tested and proven on the job. After three years of continual exposure to corrosive fumes, moisture and salt spray, CORLAR coating on right side of lime tank is still in good condition. Commonly used phenolic resin coating on left side, however, has deteriorated completely—permitting rust and corrosion to take over.

CORLAR^(T.M.)

Epoxy Chemical-Resistant Enamels



BETTER THINGS FOR BETTER LIVING...THROUGH CHEMISTRY

New Defense Against Corrosion (and Mounting Maintenance Costs!)

**Du Pont CORLAR^(T.M.) Epoxy Enamels Afford
Excellent Resistance to Chemical Spills and
Fumes, Moisture and Heat up to 400° F.**

Now a new kind of protective finish can help you solve *difficult* corrosion problems—and hold down skyrocketing maintenance costs. CORLAR Epoxy Chemical-Resistant Enamels combine excellent resistance to atmospheres containing mineral acids, alkalies, strong aromatic and aliphatic solvents with remarkable adhesion and heat resistance. They're also easy to handle, weather well, remain flexible at low temperatures.

Key to the success of these new coatings is a polyamide activator that binds molecules into a hard, firm film that literally *locks out* corrosion. Amide activator also makes CORLAR finishes safer to use and more stable; gives them 10-15 times longer pot life than amine types. Moreover, the epoxy resin's outstanding adhesion helps coatings stand off deterioration for years.

Two-package CORLAR Epoxy Enamels can be used indoors or out with equal success, apply easily with brush, roller or spray. Five standard colors are available, as well as black and white.

For prolonged exposure to severe mineral and organic acids, use Du Pont IMLAR^(T.M.) vinyl coatings. See your local Du Pont sales representative for expert technical help. For more detailed information on these new finishes, clip and mail the coupon *today*.

E. I. du Pont de Nemours & Co. (Inc.)

Finishes Division, Department C-15
Wilmington 98, Delaware

Please send me, without obligation:

- ☐ Du Pont Technical Bulletin, "CORLAR Epoxy Chemical-Resistant Enamel"
☐ Du Pont Technical Bulletin, "IMLAR Vinyl Coatings"

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Materials Literature

Cleaners

Two improved sulfamic acid base cleaners for removing scale on equipment are available from the Power Chemicals Division of E. F. Drew & Co., Inc., 15 E. 26th St., New York 10, N. Y. They are a fast acting powdered scale remover inhibited to prevent corrosion and foaming and a specialized acid cleaner claimed to be safe for use in systems containing galvanized metal, according to the manufacturer.

An ultrasonic cleaner using transistors and designed for adjustable power levels and automatic compensation for load and liquid levels is being manufactured by Acoustica Associates, Inc., 10400 Aviation Blvd., Los Angeles 45, Cal. Use of transistors in the cleaner eliminates the usual warm-up time.

Coatings, Application Equipment

Airless spraying equipment for internal surface finishing of drums, cans and other production parts requiring coating of inside areas has been developed by Spraying Systems Co., 3201 Randolph St., Bellwood, Ill. The equipment includes tungsten carbide tips and orifice inserts that project a flat spray at right angles to the nozzle.

Rugged transistorized construction practically eliminates maintenance costs... extends battery life to a year or more. Pinpoint accuracy, greatest depth penetration make the M-scope first choice in the field! Only \$189.50

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Dept. CO-7, Palo Alto, Calif.

A light weight, portable slurry and texture gun designed for spraying texture paint, acoustical plaster, waterproofing and sand finish coats is available from Air Placement Equipment Co., 1000 West 25th St., Kansas City 8, Mo. Called the Spray-Tex, the gun has a 4000-square-foot capacity per day and weighs only 125 pounds. It has an adjustable feed control on the hopper and a built-in compressor powered by a 1 hp, 60-cycle, 110-volt motor.

Coatings, Metallic

Vacuum coated refractory metals such as tungsten and molybdenum have been developed where the coating is diffused into the base metal to form a permanent bond, according to Vacuum Technology, Inc., Van Nuys, Cal. Coatings which can consist of one or more metals or alloys can be varied in thickness from a few molecules to 0.005-inch. Coatings which can be supplied include the noble metals, aluminum, nickel, various alloys and dielectrics.

Automated metal finishing operations, machines and equipment are described in an illustrated guide published by the Meaker Company, Subsidiary of Sel-Rex Corp., Nutley 10, N. J. Titled "When to Automate," the guide includes tables showing electrochemical equivalents of base and noble metals, data on depositing zinc, copper, tin, nickel, cadmium and chromium and separate tables for use with acid, cyanide and other recommended solutions.

Inspection manual governing protective zinc coatings on products hot dip galvanized after fabrication of probable use to product inspectors, designers and engineers is available from American Zinc Institute, Inc., 292 Madison Ave., New York 17, N. Y. Entitled "Inspection Manual for Hot Dip Galvanized Products," the 34-page book was prepared to help manufacturers achieve optimum corrosion protection from the galvanized coatings on their products.

Previously unattainable component tolerances in application of brazing materials are claimed possible with a plasma gun spray system. Tolerance reduction is possible because the brazing powders are sprayed in a non-oxidizing plasma, according to the manufacturer, Avco Research and Advanced Development Division, 201 Lowell St., Wilmington, Mass.

Coatings, Organic

Vinyls, epoxies, acrylics, alkyds and other plastic coatings designed for industrial uses are discussed in a 15-page brochure available from the David E. Long Corp., 220 East 42nd St., New York 17, N. Y.

An acrylic film-forming resin that dries at room temperature to a clear, glossy, water insoluble film has been developed by B. F. Goodrich Chemical Co., 3135 Euclid Ave., Cleveland 15, Ohio. Called Carboset 511, the resin is compatible with water dispersions of most polymers and adheres well to metal, glass, paper

and leather and to plastics such as polyethylene and vinyl films, according to Goodrich Chemical.

Filters

Disposable cores with acid resistant and heat resistant qualities have been designed for the depth-wound filter for use in electroplating applications. The new core is made of polypropylene and is said to be one-tenth the cost of polyvinyl chloride cores now in common use in applications where resistance against corrosive materials is required. The new cores are available from Filterite Corporation, Timonium, Md. When combined with Filterite's windings, the new core is designed for use in electroplating solutions, alkalies and other corrosive filtrates.

Polypropylene filter fabrics designed for service in plate and frame presses, rotary vacuum filters and dust collection are being marketed by Technical Fabricators, Inc., 136 Washington Ave., Nutley, N. J. The fabrics are recommended for use in hot corrosive applications involving the separation of gelatinous precipitates and fine or abrasive dusts.

Fittings

Tube and reducers that consist of only a reducing seat and nut are described in a catalog available from Special Screw Products Co., Bedford, Ohio. The seat is inserted into the fitting body to step-down tees, ells and unions. No adapter body is used, and no additional space or clearance is needed, according to the manufacturer.

Flow area is not reduced or expanded by a new type polyvinyl chloride fitting for PVC tubes made by a manufacturer in the Netherlands, according to the Netherlands Trade Commission, 10 Rockefeller Plaza, Suite 1123, New York 20, N. Y. Recently introduced to the American market, the fittings are claimed to be immune to cracking as a result of heat-sealing and are resistant to extreme hot and cold temperatures of chemicals and other liquids. The manufacturer is W. J. Stokvis' Koninklijke Fabriek van Metaalwerken N.V.

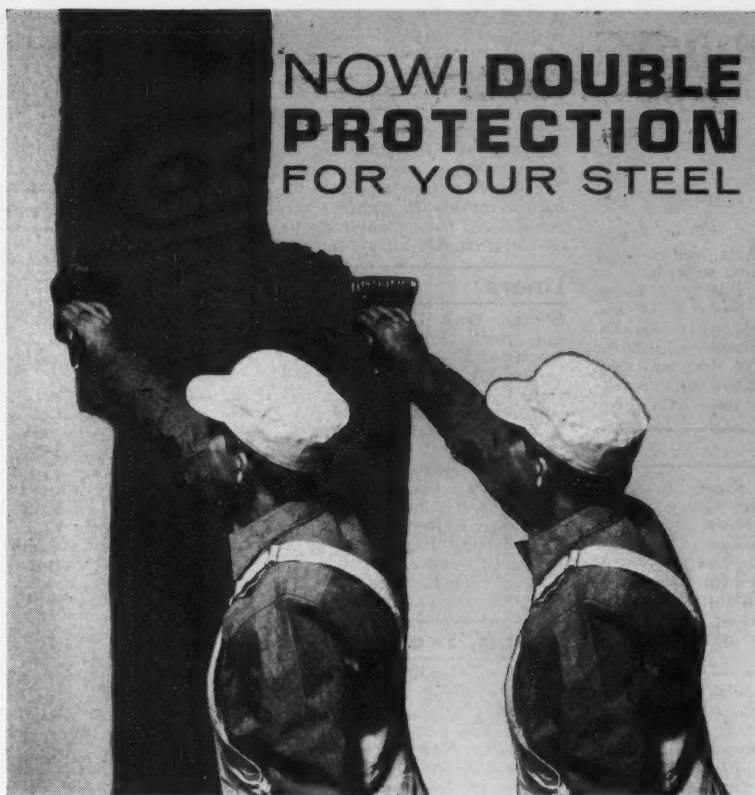
Stainless steel sanitary fittings, valves and tubing are described and illustrated in a 20-page booklet available from Terriss-Consolidated Industries, 22 Wooster St., New York 13, N. Y.

Inhibitors

Data sheets on a film forming organic inhibitor that normally inhibits corrosion of ferrous surfaces by hydrochloric acid are available from Atlas Powder (Company's Chemical Division, Wilmington 99, Del. Called Atcor HC, the inhibitor is a complex, high molecular weight amine blend.

Residual fuel oil treatment designed to minimize slag and corrosion in boiler

(Continued on Page 42)



CARBO ZINC 11* *as a primer—
protection continues even after topcoats are penetrated*

Carbo Zinc 11 is an inorganic zinc-filled coating which gives protection similar to galvanizing. It is used either as a lining, a one-coat maintenance system, or a primer with color topcoats.

You can topcoat Carbo Zinc 11 in color with any of these generic types: epoxy-ester, catalyzed epoxy, vinyl, Hypalon, chlorinated rubber. Choose the correct topcoat that meets your chemical or weathering exposure requirements—and upgrade your present protection.

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Application advantages: use spray, brush or roller—at temperatures from 0° F. to 150° F., at humidity to 95%. Water insoluble in 20 minutes. No curing solution or subsequent surface preparation required.

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*Patent applied for

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NEW PRODUCTS

(Continued From Page 40)

systems is described in a bulletin available from Nalco Chemical Co., 6216 West 66th Place, Chicago 38, Ill. Case study and application methods are included.

A new series of oil soluble, non-metallic corrosion inhibitors are described in technical bulletins available from Kessler Chemical Co., Inc., State Road and Cottman Ave., Philadelphia 35, Pa. These inhibitors are recommended for inhibition of corrosion of iron and steel when used in preservative oils, slushing compounds and greases.

Insulation

Rigid urethane foam sheets designed for high efficiency, space-saving insulation have been introduced by Allied Chemical's Barrett Division, 40 Rector St., New York 6, N. Y. The closed-cell urethane is recommended for perimeters, freezers, cold storage plants and other heat and cold retaining applications which require light weight and minimum space.

Flexible urethane foam with an adhesive backing has been developed by Air-O-Plastik Corp., Union City, N. J. After removal of the paper backing, the foam adheres to any clean, dry surface, according to the manufacturer, and is recommended for cushioning, insulating and sealing applications.

A ceramic fiber insulation reported to withstand continuous operating temperatures to 2300 F has been developed by the Carborundum Company, Niagara Falls, N.Y. Called Fiberfrax, the insulation is expected to have applications such as combustion chamber linings for oil and gas fired furnaces, components for processing molten aluminum, industrial heat treating and brazing furnaces, high temperature gaskets and packing, missile and rocket applications and high temperature gas filtration.

Liners

Special tank liner sheet material 40 mils thick for use at temperatures as low as 43 F has been developed by Flexi-Liner Co., Box 767, Pasadena, Cal. Called J-22, the lining material is designed for lining tanks for protection against chemical solutions.

Five-year guarantees are being given on factory installed concrete linings on storage water heaters manufactured by Patterson-Kelley Company, Inc., East Stroudsburg, Pa. The lining is a 3/4-inch hydraulic cement coating which is claimed not to chip, crack or flake at temperatures exceeding 880 F.

Metals, Exotic

Expanded facilities for production of titanium tubing for use in the chemical industries are being built by Titanium Metals Corporation of America, 233 Broadway, New York 7, N. Y. Seamless tubing and welded and redrawn tubing will be produced in sizes from 1/2-inch to three inches in diameter in lengths to 30 feet. Titanium Metals is a jointly

owned subsidiary of Allegheny Ludlum Steel Corporation and National Lead Company.

High purity tellurium metal in commercial quantities is being produced by Penn Rare Metals Inc. The metal is sold through Kaweck Chemical Co., Boyertown, Pa.

Metals, Ferrous

A new 18 percent nickel alloy steel has been developed for civilian and defense applications involving exceptionally high pressure and stress requirements. The alloy has the ability to achieve a yield strength over 250,000 psi while maintaining a nil ductility temperature below 80 F, according to International Nickel Company, Inc., 67 Wall St., New York 5, N. Y., developer of the new alloy. Strength is developed by a remarkably easy heat treatment involving age-hardening of martensite. This treatment has been given the abbreviated description of mar-aging. The new steel has a nominal composition of 18 percent nickel, 7 percent cobalt, 5 percent molybdenum and less than 0.5 percent titanium with a maximum 0.05 percent of carbon.

High strength columbium-treated steels formulated to have about twice the atmospheric corrosion resistance of mild carbon steel are being marketed by Jones & Laughlin Steel Corp., 3 Gateway Center, Pittsburgh, Pa. This improved corrosion resistance is achieved by addition of copper to columbium-treated steels, according to Jones & Laughlin.

Plastics

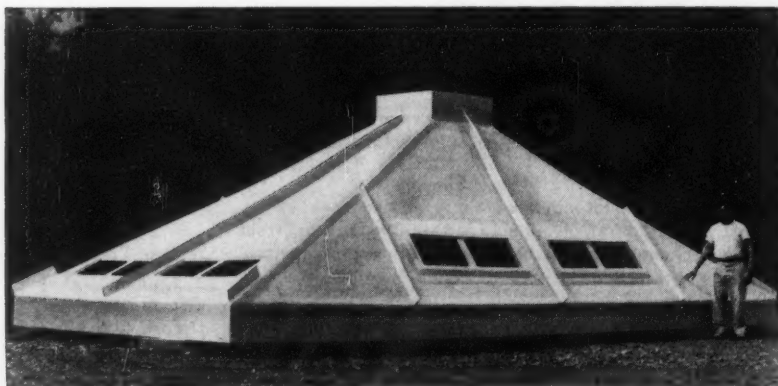
Filament wound glass fiber products such as large diameter tanks will be manufactured at the new plant recently built by Black, Sivalls & Bryson, Inc., Ardmore Industrial Air Park, P. O. Box 749, Ardmore, Okla.

Fiber glass plastic processing vessels in ten standard diameters with capacities from 40 to 70,000 gallons are fabricated by Jones & Hunt, Inc., Gloucester, Mass. Basic tank is translucent with a direct reading gauge molded into the wall.

Basic application information and engineering data on laminated plastics and vulcanized fiber are given in a new catalog published by Taylor Fibre Co., Norristown, Pa. Catalog is designed to help engineers select and apply these basic materials for electrical, electronic and mechanical components.

A new resilient topping for concrete floors which can be mixed in conventional mortar boxes or concrete mixers has been developed by Pennsalt Chemicals' Corrosion Engineering Products Department, Natrona, Pa. Called Penn-trowel Latex, the two-component mortar is recommended for a variety of industrial flooring applications.

Hollow spheres of high density tetrafluoroethylene can be used to solve flotation problems in highly corrosive fluids, according to Chemplast, Inc., 3 Central Ave., East Newark, N. J., manufacturer of the plastic balls that can be obtained in sizes from 20 to 100mm in diameter. A 4-inch diameter ball of the TEE- (Continued on Page 44)



ANOTHER BIG CORROSION PROBLEM

Solved by *duVerre*

Size is no problem at du Verre. This huge vent hood is over 20 feet wide and was designed to provide trouble-free corrosive fume removal. Two such units completely filled a large size railroad car.

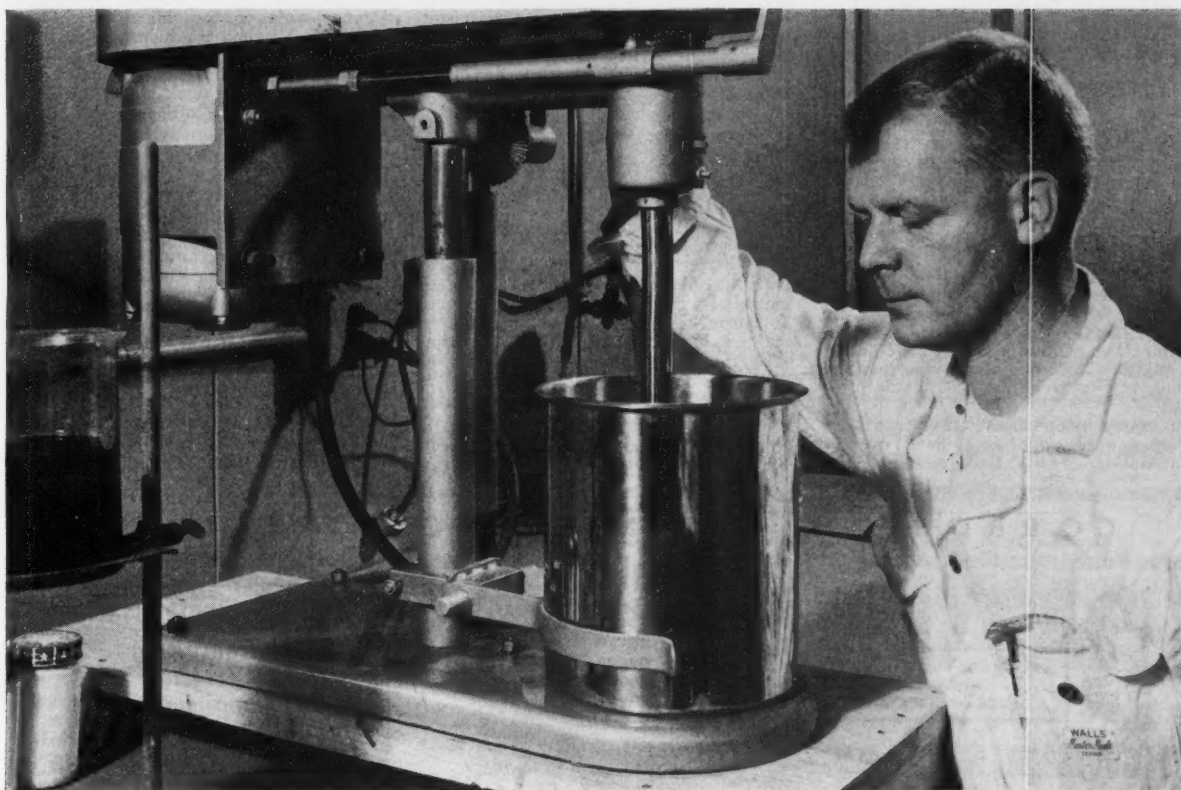
Over a wide range of corrosive and erosive conditions, du Verre Resin Bonded Fiberglass has proved its superiority over coatings, linings and other traditional "resistant" materials. Completely homogeneous, du Verre fabricated ducts, fittings, hoods and tanks provide uniform protection from flange to flange, inside and out. One-quarter the weight of steel, du Verre fabrications also save you money on freight, handling and erection. Whatever your process needs, equipment can be du Verre fabricated to your specifications. Write today. Ask for Bulletin No. 101 and see how du Verre can eliminate the high cost of corrosion and product contamination.



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From TLC Research . . .

TWO NEW PRODUCTS TO RESIST CORROSION

Two more products have joined the growing line-up of new products and processing techniques developed by Tubular Lining Corporation's Research Laboratory. TLC-44 and TLC-77 have been developed to offset salt water disposal and high temperature corrosive conditions.

Here are the product specifications developed by TLC Research:

TLC-44: This is a phenolic resin especially designed to give extreme film flexibility and good resistance to salt water disposal conditions. It is a baked-on multiple film, high-build lining of 6-8 mils. Recommended temperature limitation is 200° F.

TLC-77: This is a special lining designed for elevated temperature conditions found in deep oil and gas wells. TLC-77 is baked on in multiple layers to 4½-5 mils.

It has excellent chemical resistance with good rigid film integrity. Recommended temperature limitations are 350° to 400° F.

New product development is next to quality production in importance at TLC. During the past three years, TLC's Research Department has developed four new lining products for oil field tubing, the "AUTO-TRONICS" and "THERMO-PICKLED" processing methods, and four new testing methods to provide quality linings that do not fail.



NEW . . . For more information about quality control, write for your free copy of *THE STORY OF QUALITY CONTROL*, an eight page description of how Tubular Lining produces a quality product.



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NEW PRODUCTS

(Continued From Page 42)

fluorocarbon resins weighs only six ounces but will support a weight of more than three quarters of a pound in water. They are recommended for use as flow meters, float valves and float level indicators in tanks storing highly corrosive fluids.

Polyester plastic films can be sealed without heat by use of a new ultrasonic device called Sonoseal. Developed by International Ultrasonics, Inc., 331 Centennial Ave., Crawford, N. J., the device uses sound waves above the audible frequency to weld the plastic film.

An epoxy resin formulation has been developed for use as a floor overlay material by Durok Building Materials,

Inc., 5 Ravine Dr., Hastings-on-Hudson, N. Y. Applied by trowel, the material incorporates a flexible component for resistance to repeated shock under heavy loads, according to Durok.

MEN in the NEWS

Shell Development Company has appointed to senior management positions at its Emeryville Research Center, Emeryville, Cal., **D. P. Stevenson** as director of Basic and General Science; **T. Baron** as director of Basic and General Engineering; **A. J. Wood** as manager of Oil Research and Development and **D. L. Yabroff** as manager of Chemical Research and Development.

NACE Member **J. D. Barnes** has been named sales representative in western

Pennsylvania, western New York, Ohio and West Virginia for industrial coatings products for the Protective Coatings Division of Pittsburgh Chemical Company. He will be located in the division's Pittsburgh office in the Grant Building.

NACE Member **Irving A. Denison**, a staff member of the Army's Diamond Ordnance Fuze Laboratories, Washington, D. C., retired March 17 after more than 40 years government service.

Pipe Linings, Inc., of Wilmington, Cal., has elected two vice presidents: **Bert Espiau** will be in charge of general administration; **Donald N. Chamberlain** will be in charge of sales and civil engineering; and both will report to **Robert C. Sargent**, executive vice president of the company.

(Continued on Next Page)

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Richard T. Dale has been appointed works manager of Resistoflex Corp., Roseland, N. J.

H. L. Evans has been appointed to the newly created position of vice president of general manufacturing, Flintkote Co., 30 Rockefeller Plaza, New York 20, N. Y.

R. E. Frankenberg has been appointed service metallurgist at the Louisville, Ohio, plant of Jones & Laughlin Steel Corporation's Stainless and Strip Division.

Paul E. Garrett has been named technical superintendent of the Fredericksburg, Va., plant of American Viscose Corp.

On March 14, **Gordon Griffiths**, quality control manager of Tuboscope Co., 2919 Holmes Road, Houston, Tex., narrated a series of slides and a color film on the origin and detection of defects in oil field tubular goods.

John H. Hartzell has been named sales representative of the Colorado territory of Pittsburgh Corning Corporation. His office will be in the Hilton Office Bldg., Suite 200, Denver 2, Colo. **John P. Kasurin** has been appointed sales representative of the Detroit territory. His office will be at 18063 James Couzens Highway, Detroit 35, Mich.

Minnesota Mining and Manufacturing Company has promoted **A. F. Jacobson** to manager of its 3M tape and adhesives, coatings and sealers plant in Bristol, Pa. **R. C. Bertelsen** has been promoted to manager of 3M's St. Paul, Minn., tape plant.

On March 2, **William V. Kahler**, president of Illinois Bell Telephone Co., was presented the 1961 Washington Award by **Raymond D. Maxson**, president of the Western Society of Engineers. The award is conferred on an engineer for "accomplishments which pre-eminently promote the happiness, comfort and well-being of humanity."

Lawrence J. Kelly has been appointed a technical representative for the Metropolitan New York Region of Union Carbide Plastics Co., Division of Union Carbide Corp. His office will be at the company's district sales office, 1051 Bloomfield Ave., Clifton, N. J.

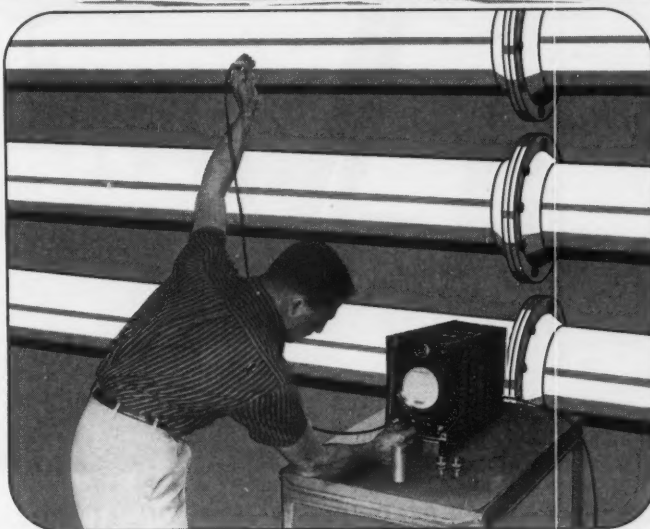
George Krsek has joined International Rectifier Corp., El Segundo, Cal., as executive vice president and general manager.

John Lubke has been named production superintendent at Odessa, Tex., by Pipe Inspectors Division of Plastic Applicators, Inc., of Houston, Tex.

John T. McCann has been named executive vice president of the Mechanical Contractors Association of America, Inc., 45 Rockefeller Plaza, New York 20, N. Y.

Frank P. Macdonald has been appointed president of Electro Rust-Proofing Corporation, 25 Main St., Belleville 9, N. J.

Willibald Machu has joined Amchem S.A., a new wholly-owned European subsidiary of Amchem Products, Inc., Ambler, Pa., as patent attorney and special technical advisor-in-residence to Amchem's European licensees. His headquarters will be in Vienna, Austria.



The Variable Angle Beam Transducer

This new transducer has been specially engineered for angle beam testing with the SONORAY® flaw detector. It incorporates a variable collimator designed to intensify the ultrasonic beam when needed. In addition to standard internal flaw detection, the variable angle beam transducer is also suitable for weld inspection and thickness gaging. The transducer is interchangeable in order to make the frequency fit the job. There are two versions of the variable angle beam transducer presently available: One for continuous water flow and the other with stationary water inside the shoe. The outstanding advantages are:

- Continuously adjustable for all angles, from straight to surface wave.
- Interchangeable transducer and beam collimators.
- Suitable for high temperature work and rapid surface scanning.
- Selection of shoes, flat or curved, to fit the surface of the work piece.

The variable angle beam transducer is further proof of the technical ingenuity and know-how of Branson's Ultrasonic Test Division. The next time you have a testing problem call BRANSON and see how fast BRANSON will find the best solution in the shortest possible time.

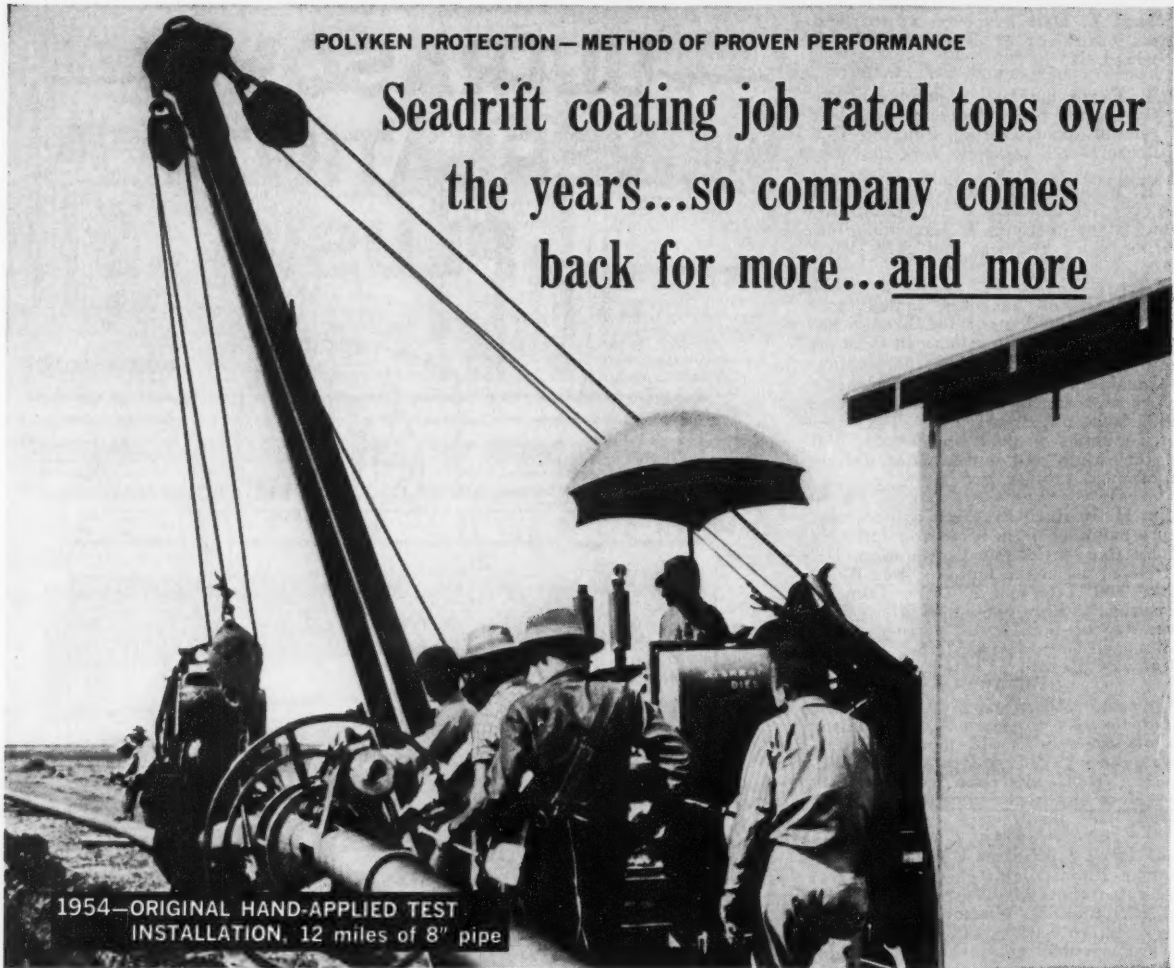
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1960—STILL ANOTHER SEADRIFT INSTALLATION, more than 300 miles of 6" and 8" pipe

1960—ANOTHER MAJOR PRODUCTS PIPELINE INSTALLATION, on 8" pipe



**Bell hole examination convinces second firm, too,
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Proof of dependable performance . . . most graphic endorsement of Polyken. In 1954, Seadrift Pipeline Co. test-installed gas pipeline from Bee County to Seadrift, Texas, wrapped with Polyken #900 Black. Very satisfactory cathodic protection requirements on the line made Polyken tape the choice again on a job from Live Oak County to Seadrift in 1957.

In 1960, a bell hole examination of the original job showed Polyken tape still in top-rated condition after 6 years. No pipe rust or corrosion. No time-wear or deterioration of tape. So, fully convinced Seadrift officials put Polyken protection to work on their 1960 projects. And engineers from *another* major pipeline company, equally impressed, ordered this *proven*

performance coating for an important part of their new products line in Iowa.

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TECHNICAL COMMITTEE ACTIVITIES

T-3F Changes Name To Explain Group's Complete Activities

The name of Technical Committee T-3F is being changed from "Corrosion in High Purity Water" to "High Purity and Related Waters" to avoid having the committee's activities overlooked by persons who might benefit and who could contribute to discussions of the problem.

The committee was originally organized to stimulate exchange of data and experience in the field of nuclear power generation where high purity water was considered a prerequisite for contact with the fuel elements which constituted the source of heat. Later, various additions were made to this water for corrosion inhibition. Additions to the water on the secondary side of the heat exchanger where steam is generated also were considered.

The inter-relation of the two problems became obvious; the committee's activities led in the direction of high temperature water corrosion reactions not well described by the exclusive term "high purity."

Persons interested in participating in the committee's activities should contact the chairman, M. C. Bloom, U.S. Naval Research Laboratory, Washington 25, D.C.

Georgia Electrolysis Group Affiliates With NACE T-7C

The Georgia Electrolysis Committee has become the 25th group to affiliate with NACE's Committee T-7 (Corrosion Coordinating Committee). The Georgia group will be under Unit Committee T-7C (Southeast Region Corrosion Coordinating Committee).

Officers of the Georgia committee are Chairman J. P. McArdle of American Telephone and Telegraph Co., Vice Chairman John O. Oates of Transcontinental Gas Pipe Line Corp., and Sec-

retary R. L. Smith of Southeastern Pipe Line Co.

Organized January 9, 1961, in Atlanta, Ga., the Georgia committee will constitute a clearing house for exchange of engineering information on underground corrosion problems arising in the state of Georgia.

Kulman Appointed Vice Chairman of Technical Practices

Frank E. Kulman, senior engineer with Consolidated Edison Company of New York, Inc., New York City, has been appointed vice chairman of Technical Practices Committee by NACE President E. C. Greco. Jack L. Battle of Humble Oil & Refining Co., Houston, Texas, was appointed chairman earlier (See Page 43, April issue of CORROSION).

An NACE member since 1946, Mr. Kulman was elected to the Board of Directors last fall as a representative of the active membership. He has been chairman of the Metropolitan New York Section, chairman of Group Committee T-4 on Utilities

and a member of several other technical committees. He also is a member of the NACE Publications Committee Editorial Review Subcommittee.

His work with Consolidated Edison Company is responsibility of corrosion control on the firm's distribution systems for electricity, gas and steam in New York City and Westchester County.

He has a master's degree in electrical engineering from Polytechnic Institute of Brooklyn.



Kulman

New Committee Officers

T-3F Officers Re-Elected

Chairman M. C. Bloom of Naval Research Laboratory, Washington, D.C., and Vice Chairman W. K. Boyd of Battelle Memorial Institute, Columbus, Ohio.

T-4G Vice Chairman

J. C. Howell of Public Service Electric and Gas Co., Maplewood, N.J.

T-6F Officers Re-Elected

Chairman W. P. Cathcart of Tank

Lining Corp., Oakdale, Pa., Vice Chairman Bernard M. Saffian of U. S. Stoneware Co., Stow, Ohio, and Secretary James H. Cogshall of Pennsalt Chemicals Corp., Natrona, Pa.

T-6G Chairman Re-Elected

Chairman Joseph Bigos of United States Steel Corp., Monroeville, Pa., and Vice Chairman John D. Keane of the Steel Structures Painting Council, Pittsburgh, Pa.



Bigos



Bloom



Boyd



Cathcart



Cogshall



Howell



Keane



Saffian

T-6B Establishes New Task Group on Silicones

A new task group was appointed at the meeting of Technical Committee T-6B (Protective Coatings for Resistance to Atmospheric Corrosion) held during the Buffalo Conference. Designated as T-6B-15 on Silicones, the new task group will be headed by Gatewood Norman of Firestone Rubber Co., Orange, Texas.

Two technical papers were given during the meeting at Buffalo. One on hot dipped galvanizing was by John Heath of Dow Chemical Company; the other was on polyurethane foams by John Lawrence of the Gliden Company.

Next meeting of T-6B will be held in Houston during the October 24-26 South Central Region Conference.

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For Today's Pipe-Joint
Protection Problem

With the introduction of plastic-coated steel pipe, users are once again faced with the problem of providing effective protection at the joints.

This is the same situation that confronted the industry in 1941 when The Tapecoat Company originated protection in tape form for pipe joints, to match the mill coating on the pipe.

Now . . . with the advent of another method of mill-coating pipe, Tapecoat has developed Tapecoat 20 to meet all joint-coating requirements. One of the many features of Tapecoat 20 is its adaptability for coating joints on pipe protected with high-density polyethylene.

Tapecoat 20 provides a compatible bond, not only to the bare pipe, but also to the jacket on the mill-coated pipe—with no bridging of the tape from the jacket to the bare pipe.

The illustrations show joints protected by Tapecoat 20. Note joint (at right) demonstrating effectiveness of bond even after Tapecoating has been pulled away from pipe surface.

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Papers Solicited for 1962 Conference Program

Names and Addresses Given for Seventeen Symposia Chairmen

Technical papers for presentation at the 18th Annual NACE Conference to be held March 19-23 in Kansas City, Mo., are being solicited. Papers will be given during 17 technical symposia as part of the conference program.

Persons interested in presenting a paper on the Kansas City program should contact the chairman of the symposium listed below in which the paper would have the greatest interest. Names and addresses are given for the 17 symposia chairmen.

Chairman for the 1962 technical program is L. W. Gleekman of Wyandotte Chemicals Corp., Wyandotte, Mich. His co-chairman is David Roller of Magna Products, Inc., Anaheim, Cal.

Cathodic Protection: Herman S. Preiser, Chemionics Engineering Laboratories, Inc., One Bala Ave., Bala-Cynwyd, Pa.

Chemical Industries: C. W. Ambler, Jr., American Zinc, Lead & Smelting

Co., P. O. Box 495, East St. Louis, Ill.

Missile Industry: Harold L. Stevens, R. R. No. 3, New Carlisle, Ohio.

Corrosion Inhibitors: Robert A. Legault, Research Laboratories, General Motors Corp., 12 Mile & Mound Roads, Warren, Mich.

Corrosion Principles: Walter K. Boyd, Battelle Memorial Institute, 505 King Ave., Columbus, Ohio.

Educational Lectures: J. James Hur, Atlantic Refining Co., P. O. Box 8016, Philadelphia, Pa.

Elevated Temperatures: Anton deS. Brasunas, American Society for Metals, Metals Park, Novelt, Ohio.

General Corrosion: Franklin N. Beck, Ohio State University, 207 Engineering

Texas. (See special notice concerning this symposium on this page.)

Protective Coatings: Joseph Ferraro, American Cyanamid Co., Bound Brook, N.J.

Pulp and Paper Industry: R. R. Pierce, Pennsalt Chemical Co., Corrosion Engineering Dept., Natrona, Pa.

Refining Industry: G. C. Hall, Richfield Oil Corp., P. O. Box 787, Wilmington, Cal.

Utility Industries: Carl M. Thorn, Southwestern Bell Telephone Co., P. O. Box 2540, San Antonio, Texas.

Slides Available On 1961 Conference And Corrosion Show

A 35mm color slide show including a prepared script on the 17th Annual NACE Conference and 1961 Corrosion Show held in Buffalo, N. Y., is available from Central Office.

The slide show was prepared by Central Office staff for use by NACE sections and other interested groups. Booking request should be sent as far in advance of use-date as possible to Durwood Levy, National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Texas.

The slides cover various activities of the conference including technical symposia sessions, registration, annual banquet, ladies program and technical committee meetings.

Majority of the slide show deals with the 1961 Corrosion Show, giving close-up views in color of the wide variety of corrosion control equipment and materials which were displayed.

The slide show is recommended for use by NACE sections at regular meetings to give some idea of the activities of the conference for the benefit of those persons who could not attend the Buffalo meeting. The slide show might be used in conjunction with a survey of the conference to be given by a section member who attended.

Extra sets of the slide show are being prepared so that better booking service can be given on this year's slide show than was experienced on the 1960 Corrosion Show slide set.

Marine Corrosion Topics Suggested for Symposium

Technical papers on recent corrosion control developments in the marine field are being solicited for the Marine Corrosion Symposium, which will be part of the 1962 Annual Conference technical program in Kansas City, Mo.

Experiences with materials involving exposure to sea water such as would be involved in the following suggested topics are especially desired: (1) seawater conversion plants, (2) heat exchangers handling sea water, (3) installations using hot sea water, (4) scale control in heating sea water, (5) alloys for high velocity impellers or propellers, (6) materials for hydrofoils, (7) corrosion fatigue in sea water, (8) high strength materials for marine structures, (9) control of corrosion in underwater instruments and (10) pipeline and cable experiences in sea water.

Persons who have interesting technical material pertinent to this symposium should contact the chairman, F. W. Fink, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio.

Experiment Station, 156 West 19th Ave., Columbus, Ohio.

High Purity Water: A. L. Meddin, U. S. Steel Corp., Applied Research Laboratories, Monroeville, Pa.

Marine Corrosion: F. W. Fink, Battelle Memorial Institute, 505 King Ave., Columbus 1, Ohio. (See special notice concerning this symposium on this page.)

Oil and Gas Production: J. A. Caldwell, Humble Oil & Refining Co., Box 2180, Houston, Texas.

Pipe Line-General: E. L. Karraker, Shell Oil Co., Products Pipelines, 8500 No. Michigan St., Indianapolis 8, Ind.

Plastics Symposium: Raymond B. Seymour, Chemistry Department Chairman, Sul Ross State College, Alpine,

Effect of Variables to Be Plastics Symposium Theme

Theme for the Plastics Symposium at the 1962 Annual Conference will be the effect of variables on the chemical resistance of plastic materials on construction.

Persons interested in presenting technical papers in this symposium should contact the chairman, Raymond B. Seymour, Chemistry Department Chairman, Sul Ross State College, Alpine, Texas.

Northeast Region

Boston Short Course Registration to Be \$15

Registration fee will be \$15 for the June 20-22 Greater Boston Section Short Course to be held at the Wentworth Institute.

Complete program for the short course appeared on Page 49 of the April issue of CORROSION.

Fundamental training in corrosion, causes of corrosion, cathodic protection and other aspects of corrosion control work will be covered.

Baltimore-Washington Section scheduled for its April 18 meeting in Baltimore a report by Harold Breslau on the "Characteristics of the Hot Dip Galvanized Coating" and, afterwards, a plant tour of the Southern Galvanizing plant.

Philadelphia Section's Past Chairmen and Ladies Night meeting May 31 to honor past chairmen will hear Robert C. DeMarco of Philadelphia Electric Company speak on "The Eddystone Electric Generating Station and Its Underground Corrosion Problems." During the summer a field trip to the Philadelphia Electric plant at Eddystone, Pa., is planned as a follow-up to this meeting.

Genesee Valley Section heard Bernard Husock of Harco Corporation speak on "Cathodic Protection" at its February 22 meeting, Rochester, N.Y.

North Central Region Conference Program Listed

Abstracts Given For 29 Papers in Nine Symposia

Complete technical program for North Central Region Conference is given below. Conference is to be held October 9-11 at the Chase Park Plaza Hotel, St. Louis, Mo.

Chairman of the technical program is F. L. Whitney, Jr., Monsanto Chemical Company, St. Louis, Mo. His co-chairman is W. B. Meyer of St. Louis Metallizing Company, St. Louis, Mo.

Monday, October 9

Protective Coatings—Inorganic

Chairman, C. J. O'Boyle of Metco, Inc., Chicago, Ill.

Refractory Flame Sprayed Coatings, by H. S. Ingham, Metco, Inc., Wesbury, Long Island, N. Y.

Applications of refractory flame sprayed coatings in the missiles and industrial fields will be discussed. Refractory coatings act as a heat barrier, limit corrosion and protect against abrasion and erosion at temperatures over 3000 F and to 6000 F. New and more effective methods of plasma flame spraying to prevent corrosion will be presented.

Practical Applications of Flame Sprayed Refractory Coatings, by W. B. Meyer and W. T. Woodson, St. Louis Metallizing Company, St. Louis, Mo.

Coatings of aluminum oxide, zirconium oxide, zirconium silicate, chrome oxide, a mixture of rare earth oxides and many others are used as thermal barriers, bearing surfaces, surface catalytic activity, electronic applications, erosion protection and corrosion control. These refractories are flame sprayed in stick or powder form through oxygen-fuel gas and plasma systems to properly prepared metals, certain plastics, graphite-carbon, ceramics, glass magnesium, fiber glass, asbestos, etc. After being applied, coatings can be impregnated with compounds to reduce porosity, increase chemical resistance or alter emissivity value. Additives are used to reduce friction.

Utilities Symposium

Chairman, R. G. Kern of Union Electric Company, St. Louis, Mo.

Cathodic Protection at Laclede Gas Company—An Interim Report, by J. C. Vogt, Laclede Gas Company, St. Louis, Mo.

Laclede Gas Company's cathodic protection program will be discussed. History of company's efforts at corrosion control, initial temporary programs on selective lines, short term evaluation of limited successful experiences and other utilities' experiences will be described including the 1952 decision to apply

cathodic protection to all new installations. Maintenance protection and eight years' experience with coated, insulated and anodized piping units are evaluated.

High Temperature Corrosion of Constant Thermocouple Conductors, by J. A. Klapper and H. Heffan, Ebasco Services, Inc., New York, N. Y.

Experiences prove that a thermocouple for service above 400 F should not be insulated with asbestos or plastic but should be covered with a high temperature ceramic. Discusses failure of Constantan conductor of a Chromel-Constantan thermocouple in reheat steam line of a steam-electric plant.

Some Corrosion Problems in Steam Electric Generating Plants, by N. J. Shimshock and J. A. Rohrig, The Detroit Edison Company, Detroit, Mich.

Discusses corrosion of aluminum siding over a five-year period, external corrosion of boiler tubes caused by water washing ash from superheaters, repeated tube failures in two superheaters because of blockage caused by oxide scale shed from internal surface of superheater tubes, and corrosion on the internal surface of boiler tubes at flash welds. Replacement of cast iron with stainless steel castings in a vital part of a coal stoker solved a serious burn-out problem.

Some Corrosion Problems in Power Plant Steam Surface Condensers, by Rush A. Wilson, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

Metal pickup problems in condensers and associated equipment, steam and water erosion on steam side of condenser and steam side cleaning and corrosion problems will be discussed. Carbon dioxide attacks in condensing equipment are discussed with some theories and explanations about use and effect of ammonia and ammonia-producing compounds on condensing equipment.

High Temperature Metals

Chairman, H. J. Siegel of McDonnell Aircraft Corporation, St. Louis, Mo.

Refractory Metals Columbium, Tantalum, Molybdenum and Tungsten, by Jack Chelius, Fansteel Metallurgical Corporation, Chicago, Ill.

Physical and mechanical properties of these four primary refractory metals, their production and available mill forms will be discussed with fabrication techniques, important applications and current refractory alloy development.

Coatings for High Temperature Protection of Columbium Alloy Structures, by Eric N. Bamberger and Ludwig Luft, General Electric Company, Evendale, Ohio.

Columbium alloys offer possibilities for structural application at temperatures above 2000 F. These alloys require protection against surface and subsurface oxidation when exposed to air at high temperatures. Protection requirements must be considered in terms of metal coating systems with special conditions imposed by type structure to be protected. Development of diffusion coating is traced from definition of problem and establishment of qualification criteria to achievement of desired performance. Named LB-2, the process involves application of 10Cr-2Si-Al and unalloyed aluminum slurries followed by diffusion heat treatment and provides protection for F-48 and Fansteel-82 alloys for exposure at least two hours in 2500 F static air.

Oxidation Rate of Refractory Metals as a Function of Pressure, Temperature and Time: Molybdenum in Oxygen, by J. N. Ong, Jr., Aeronutronic, Inc., Newport Beach, California, and J. F. Brady, McDonnell Aircraft Corporation, St. Louis, Mo.

By assuming that oxide layer formed upon reaction of molybdenum with oxygen is non-protective, an equation capable of predicting the linear oxidation rate at various temperatures and pressures was developed from fundamental chemical kinetic principles. This equation will be discussed.

Tuesday, October 10

Brewing Industry

Chairman, C. L. Griffin of Anheuser-Busch, Inc., St. Louis, Mo.

Materials of Fabrication, by E. W. Kleefisch, Nooter Corporation, St. Louis, Mo.

Construction materials most used in the brewing industry, their fabrication methods and problems and material finishes and cleanliness will be discussed, including methods of cleaning and their effects on equipment.

Corrosion in Brewery Packaging Operations, by B. E. Nordheim, Carling Brewing Company, St. Louis, Mo.

Metallic and non-metallic corrosion of package and product handling equipment and building facilities will be discussed. Bottle cleaning machinery, pasteurizers, bottle conveyors, fillers, tanks and floors are designed to cope with corrosion; in-plant preventive maintenance also reduced corrosion losses. Major cost of initial investment and annual maintenance indicates vast corrosion problem in brewing industry.

Corrosion in Beer Producing Facilities, by J. Mueller, Anheuser-Busch, Inc., St. Louis, Mo.

Corrosion of brewing and aging vessels, machinery and piping required to transport raw products in dry form and finished product in liquid form will be discussed. Outlines lower operating and maintenance costs achieved by selecting proper materials to control corrosion.

Petroleum Refining Industry

Chairman, W. A. Heideman of Mobil Oil Company, East St. Louis, Mo.

Wood Maintenance for Water Cooling Towers, by J. L. Willa, Cooling Tower Institute, Houston, Texas.

Presents eight-year study of wood maintenance problems conducted by Cooling Tower Institute. Study covers yearly inspections of 103 towers, correlation of observed tower conditions with circulating water components and tower maintenance practices, and installation and inspection of 745 treated test panels of four species with eight different preservative chemicals in 21 operating towers.

Stress Corrosion Cracking Studies of Austenitic Stainless Steels in Aqueous Ammonium Chloride Solutions, by E. B. Backensto and A. N. Yurick, Socony Mobil Oil Company, Paulsboro, N. J.

Discusses susceptibility of 300-series stainless steels to stress corrosion cracking in aqueous NH₄Cl solutions, determined by exposing highly stressed, sensitized wires to test solution and recording time to failure. Effects of following variables will be reported: solution concentration, pH, air, H₂S, type of neutralizer and presulphation of test wires.

Transportation Industry

Chairman, Louis Shaywitz of Transportation Materiel Command, U. S. Army, St. Louis, Mo.

Selection of Protective Coatings for Highway Vehicles, by K. L. Raymond, General Motors Corporation, Pontiac, Mich.

Describes study made on proof testing of coatings for vehicles. Basic research into characteristics affecting paint durability is supplemented by accelerated laboratory examinations; production trials to avoid costly shutdowns and repairs are conducted to determine whether operating and application schedules can be maintained. Customer acceptance surveys and 25,000-mile competitive durability tests are described.

Corrosion Problems Encountered in the Marine Field by the U. S. Army, by Lt. Col. O. R. Dinsmore, Army Reactors Branch, A.E.C., Washington, D. C.

The Transportation Corps is providing marine equipment for the U. S. Army. This involves manufacture and storage of military marine equipment, both afloat and ashore, in or near salt or other corrosive atmospheres. Equipment on vessels is vulnerable to corrosion. The Army experimented with cathodic protection of underwater hulls and cleaning of cargo tanks and recently has begun to dehumidify and cocoon complete vessels. Problems with marine equipment now in the standard fleet and their solutions are discussed.

Corrosion Problems in the Aircraft, Marine, Railroad and Truck Transport Industries, by E. W. Everhart, Kaiser Aluminum and Chemical Sales, Inc., Chicago, Ill.

Corrosion problems in aircraft, marine, railroad and truck transport industries will be reviewed and methods of designing to limit susceptibility to corrosion and stress corrosion discussed. Preventive measures, choice of more resistant materials and metallurgical considerations will be described.

(Continued on Next Page)

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Non-Metallics Symposium

Chairman, J. F. Revilock of National Carbon Company, Division of Union Carbide Corporation, Cleveland, Ohio.

Nucerite, a New High Temperature Corrosion Resistant Material, by D. H. Hall and J. R. Little, Pfaunder Company, Rochester, N. Y. Operating temperatures of corrosion resistant glassed steel systems were limited to about 500 F until recent development of Nucerite, a family of crystallized glass-metal composites which allows operating temperatures as high as 1500 F. In the future, even higher temperatures may be possible. Relationship between microstructure and physical properties will be noted, and the manufacture of Nucerite and results of physical and chemical tests described.

Corrosion of Glass Reinforced Polyester Plastic under Action of External Forces, by O. W. Siebert and E. G. Wood, Monsanto Chemical Company, Monsanto, Ill.

Test results are reported on corrosion resistance of glass reinforced polyester plastic sheet subjected to tensile stresses. This report is part of a study concerned with corrosion as a function of external forces applied to structures of reinforced polyester plastics. Test methods and evaluations are discussed.

Low Permeability Graphite Materials and Their Engineering Applications, by R. P. Stambaugh and J. L. Revilock, National Carbon Company, Division of Union Carbide Corporation, Cleveland, Ohio.

Development of low permeability graphite construction materials for use in corrosion resistant equipment will be outlined. Impervious graphite produced by resin impregnation of graphite was first material of this type to offer ultra-low permeabilities and has been used in corrosion applications such as heat exchangers, centrifugal pumps, towers and absorbers. Graphites of low permeabilities, produced by methods other than resin impregnation, are becoming available. Having no temperature limitations other than those of carbon or graphite, they are being used in nuclear and high temperature applications. Characteristics, properties and costs of these materials will be reported with their applications and design considerations based on present, planned and long range usage.

Wednesday, October 11

Protective Coatings—Organic

Chairman, S. L. Lopata of Carboline Company, St. Louis, Mo.

Effects of Ultraviolet Light Upon Physical Properties of Neoprene and Hypalon Coatings, by G. K. Vogelsang, Gates Engineering Company, Wilmington, Del.

Deals primarily with Neoprene and Hypalon but includes comparative data on vinyls, epoxies and urethanes. Elastomeric Neoprene and Hypalon coatings were selected because changes in tensile strengths and elongations can be readily followed, and the effects of antioxidants and antiozonants, ultraviolet absorbers, etc., lend themselves to study.

Budgeting and Selling a Paint Program, by W. E. Chandler and T. F. Stanley, Monsanto Chemical Company, St. Louis, Mo. Selling a paint program begins with analyzing the prospect's needs, ends when the prospect is convinced that the proposed program will benefit him more than any other program. Gives steps in developing a program.

Method for Evaluating Built-up Roofing, by C. R. Martinson, Monsanto Chemical Company, St. Louis, Mo.

An illustrated presentation describing development of roof evaluation method. Covers various testing methods and their correlation. Progress and problems in applying test results to field repair and new construction will be discussed.

Metals for Process Industry

Chairman, H. O. Nordquist of Jos. T. Ryerson & Sons, Inc., St. Louis, Mo.

Stainless Steels—Their Use and Maintenance in Process Industries, by W. G. Renshaw, Allegheny Ludlum Steel Corporation, Brackenridge, Pa.

Alloy designations and characteristics will be discussed, including welding and heat treatment and uses. Types of corrosion and their prevention by proper design, fabrication and maintenance will be stressed.

Titanium—A Basic Material for Chlor-Alkali Processing Industry, by D. B. Dik, Titanium Metals Corporation of America, New York, N. Y.

Wet chlorine gas and chlorinated brine solutions create severe corrosion problems which are only partly solved by non-metallic materials such as ceramics, rubber, concrete and plastics. Marketing research reveals promise

for titanium equipment in chlorine production provided metal prices continue to decline and fabricating techniques are improved. Possible applications are for platinum plated titanium anodes to replace graphite; titanium heat exchangers for cooling cell gas to replace glass, rubber and graphite; titanium-lined towers, ducts and cells to replace plastics, rubber, etc.; titanium compressors and pumps to handle wet gas directly without expense of drying to allow use of steel; and miscellaneous equipment such as valves and tubes.

Aluminum Advancements in the Chemical Process Industry, by R. S. Dalrymple, Reynolds Metals Company, Richmond, Va.

Development of low cost, efficient welding techniques and resin bonding have opened new applications of aluminum. Aluminum alloys are used for process pipe lines, storage tanks, shipping containers, heat exchangers, instrument air lines, rail and road tankers, fume ducts, electrical conduit, bus bar, filter press beds, pump casings, pipe jacketing and other items. Alclad aluminum alloys are used to overcome corrosive service; architectural applications of aluminum alloys are found in the chemical process industry where aluminum roofing, siding, flashing, gutters and window frames must withstand atmospheric corrosion of a chemical plant.

Sheet Linings Symposium

Chairman, G. P. Kern, Garlock, Inc., Camden, N. J.

Natural and Synthetic Rubbers Including Plasticized Polyvinyl Chloride, by R. D. Bailey, Automotive Rubber Co., Inc., Detroit, Mich. Proper corrosion resistant barrier is determined by evaluating types of corrosives present, temperature, abrasiveness of products, size and location of the installation and product contamination; elastomeric linings are not an exception to this rule. Natural synthetic and plasticized polyvinyl chloride linings cover a large percentage of corrosion problems in the growing complex of chemical combinations. Improvements have been made in elastomeric formulations and their adhesive systems. Blending of various natural and synthetic materials has improved linings used in chemical, steel and paper industries as well as other fields involving corrosion problems.

Field Experiences with Penton Tank Linings, by George Taylor, Hercules Powder Company, Wilmington, Del.

Application techniques, high temperature chemical resistance and field experiences showing typical installations of Penton tank linings will be discussed. Sheet linings for large tanks and processing vessels can be applied to low-cost metal substrates using an adhesive system and conventional techniques and equipment. Penton sheet linings have been used for severely corrosive liquids at elevated temperatures and for electroplating baths, metal pickling and bright dipping, chemical milling, spent acid storage and environments involving acid-solvent mixtures. Discussion of field installations will in-

clude slide pictures of electroplating baths, decanting systems, condenser units, chemical milling operations, railroad tank cars and several processing vessels.

Fluorocarbon Linings, by C. R. Payne, Electro Chemical Engineering & Mfg. Co., Emmaus, Pa.

Case histories of Teflon sheet applied as linings to various tanks and equipment in selected areas of the chemical processing industry will be discussed.

Chicago Section held a panel discussion on coatings March 21. Moderated by Richard Rue of Pittsburgh Chemical Company, the panel consisted of Lawrence N. Redlin of Redlin, Inc., Kenneth Peisker of Kenneth Peisker Company, Len Risetter of Industrial Coatings Corporation and Daniel G. Keefe of Swift & Company.

Technical Practices Committee Report Given for 1960-61

The association's technical committees continue to be very active, according to the report of the Technical Practices Committee given to the president of NACE, covering the period February 1, 1960, to February 1, 1961.

Twelve technical committee reports were published in CORROSION in 1960, and two reports were published separately. Over 122,000 copies of technical committee reports were put into circulation. An income of \$1362 was realized from sale of these reports.

Numerous committees continue to hold meetings between conferences. Twenty-seven meetings were held during the 1960 regional conferences. Membership in committees now totals 1569. Thirty-one new activities were begun in 1960, including six new unit committees and 25 new task groups.

A Technical Committee Operation Manual and Technical Committee Directory was published during the year.

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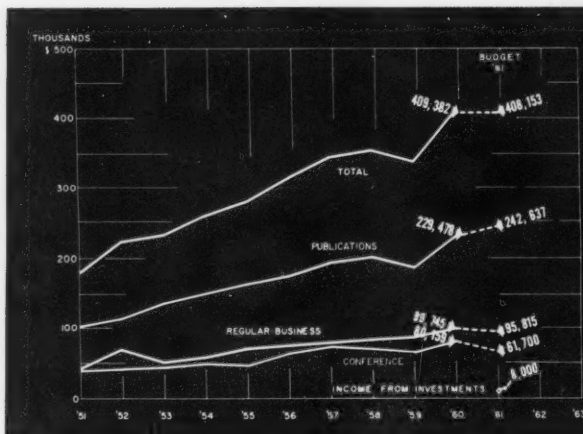


Figure 1—NACE Income

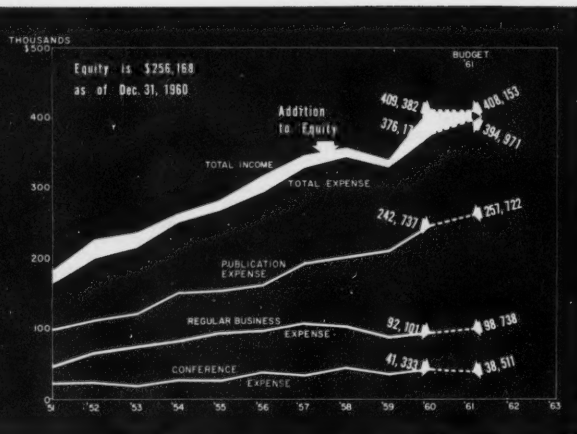


Figure 2—NACE Application of Funds

Treasurer's Report Given at Buffalo For 1960-1961

Last year at the conference in Dallas, I presented the Report of the Treasurer for A. L. Stegner, who was then treasurer of NACE and who could not attend the conference for business reasons. This Report of the Treasurer covers my first year in that office.

It is, naturally, very pleasant for me to report that during the year 1960, NACE realized the largest net income over expenses in the history of the association. This happy situation reflects, more than anything else, some very good judgment on the part of the Finance Committee. I was not on the Finance Committee at that time and can claim no credit.

In 1958, the association's Finance Committee reviewed the NACE income and expense figures for several preceding years and found the association had been operating with a very small margin of income over expenses. The margin was from 3 to 4 percent. An operating margin this small has a very slight margin of safety and can become dangerous if continued.

The committee recommended to the Board of Directors that the association's annual income be increased through increased active and corporate member dues and items of income from publications. The committee further recom-

mended that the increased income should be large enough that the association's operating margin of income over expenses should be from 8 to 10 percent of the annual income.

In 1960, the margin of income over expense was slightly over \$33,000. This amounted to a little over 8 percent of the 1960 income.

Total expenses for 1960 were slightly in excess of \$376,000. I am sure you will agree the \$33,000 net is not an exorbitant margin though much safer from an operating point of view than the 3 to 4 percent margin experienced in past years.

The year 1960 saw the association operating close to the budget established by the Board of Directors. Total association income was about \$8500 less than budgeted income. Total association expense was about \$5800 less than budgeted. With these figures practically balancing, the association's net income over expense was just \$2700 less than the budget figure. Considering that the 1960 conference net income over expense was some \$8000 less than estimated for budget purposes, we feel that regular business and publications had an exceptionally good year to make up over \$5000 of this difference.

It is customary each year for the treasurer to present to the membership a series of charts and graphs showing association income, expense and application of funds.

Figure 1 represents NACE income from all sources. Conference income shown by the bottom line was \$80,159

for 1960. Second line from the bottom represents income from regular business: \$99,745 in 1960. The second line from the top shows income from association publication including CORROSION. This income was \$229,478. The top line represents total NACE income, which was \$409,382 for 1960. Dotted portions of each line represent budget figures for 1961.

I want to point out one thing here but will reserve a complete discussion until later in this report. Please notice the difference in regular business income in 1960 and the regular business income budget figure for 1961. The '61 budget figure is some \$4000 less than that reported for 1960. Now, notice the point on 1961 labeled "Income From Investments" at the bottom of the chart in Figure 1. This is a budget figure of \$8000. Through 1960, income from association investments were reported in regular business. For 1961 and hence, we have decided to separate income from investments from regular business and show it as a separate item on our financial statements. Actually, the money invested by NACE has come from publications and conference as well as from regular business. It would be difficult to try to break down that portion of invested funds that came from each of the three accounts. This fact, together with a new NACE investment program which I will discuss in detail later, prompted us to separate income from investments from the regular business account. The important point is that there is no reduction in income.

Figure 2 represents application of NACE funds. The bottom line is conference expenses of \$41,333. The next line is regular business expenses totaling \$92,101 for 1960. The third line from bottom shows publication expense for 1960 was \$242,737. Second line from the top represents total association expenses of \$376,171.

The top line of Figure 2 represents total association income of \$409,383. The difference between total expense and total income is the amount that was added to association equity. In 1960, this amounted to \$33,211. The dotted lines again represent 1961 budget figures.

The difference between total expense and total income in the 1961 budget is considerably less than the difference for 1960. This comes from the much smaller net expected from the 1961 conference

(Continued on Page 56)

ASSETS		LIABILITIES & ASSOCIATION EQUITY	
CURRENT ASSETS		CURRENT LIABILITIES	
TOTAL	181,299	TOTAL	11,303
INVESTMENTS		AMTS. RECEIVED IN ADVANCE	
Shares in Savings Assns.	28,000	TOTAL	81,234
Corporate Stocks	30,688	REVENUE DEFERRED	
TOTAL	158,688	TOTAL	20,472
SPECIAL FUNDS		CONTRIBUTIONS FOR RESEARCH AND EDUCATIONAL PURPOSES	
Educational Fund	1,711	TOTAL	1,596
FIXED ASSETS—AT COST		ASSOCIATION EQUITY	
Office Furn. and Equip.	30,530	TOTAL	256,168
Less: Reserve for Depr.	13,540	TOTAL ASSOCIATION LIABILITIES AND EQUITY	
Fixed Assets—Net	16,990		370,773
DEFERRED EXPENSES			
TOTAL	2,085		
TOTAL ASSETS	370,773		

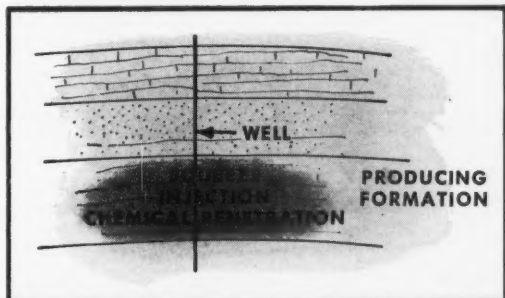
Figure 3—Condensed Balance Sheet

Visco Squeeze Treatment Chemicals Designed to Fit Varying Well Conditions

Corrosion Control Lasts, Costs Less with New Visco Formulas, Methods

Squeeze treatment in producing wells continues to grow in importance as an economical, long-term method of obtaining effective corrosion control. It is simply the pressure injection of corrosion inhibitor chemical into the producing formation, from which it is released in approximate proportion to produced fluid volume over a period of time—anywhere from two to sixteen months.

Visco has found squeeze treating of sufficient interest to producers to justify development of specialized chemicals and techniques to permit most effective use of the method.



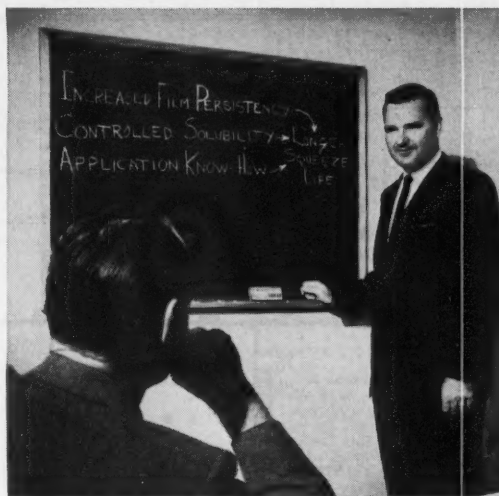
Squeeze technique forces chemical corrosion inhibitor into formation around well bottom. Chemical is carried back with produced fluid. The excellent film persistency of Visco squeeze treating chemicals assures long-lasting, low-cost well protection.

Effects of Formation

Producing formation composition, porosity permeability and position can have an important bearing on the success of squeeze treatment corrosion control... They are important considerations in the development of special Visco formulas for this purpose.

Determining Chemical Type

As with any operation affecting producing formations, experience is the most dependable guide. Chances are great that the conditions you have in your area have been closely paralleled by other Visco squeeze treating experience. Further, Visco Formulas such as



Visco's P. H. Mallette, Product Manager for Corrosion Control Chemicals, discusses factors considered important in assuring effective squeeze treatment.

new 939, 956, and 990, were developed to broaden the effectiveness of corrosion control with squeeze treatment, and so are a big help in pinpointing the best chemical and method to apply to specific well characteristics.

Field Experience

Squeeze treating can offer some substantial cost and time advantages for effective corrosion control in many types of producing wells... BUT, probably more than any other treating method, squeeze treatment demands skill and experience, as well as effective chemicals, to assure success. No one is better equipped than Visco... we firmly believe no one else can do as well for you.

Help, Now

Visco action toward being useful in your activities is as close as your phone—and nearly as quick as picking it up. Your move.

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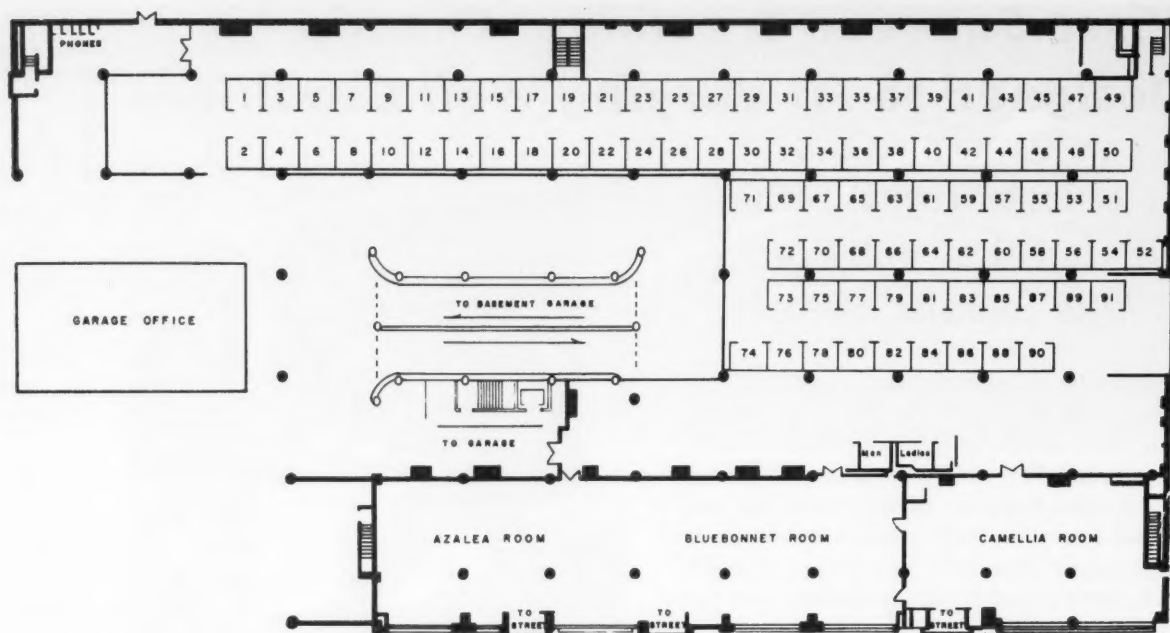
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South Central Region

Fourth South Central Region Exhibition To Be Held October 24-26 in Houston

Early contracts received for booth space at the 4th South Central Region Exhibition to be held October 24-26 at the Shamrock Hilton Hotel, Houston, Texas, indicate that the exhibition may be the largest ever held by the region.

To be held concurrently with the South Central Region Conference, the exhibition will have 91 booths for companies to display the latest techniques, materials, methods and equipment in corrosion control.

The exhibition will be held in an area adjacent to the meeting rooms for the technical program of the conference. The floor plan in accompanying illustration shows the Azalea, Bluebonnet and Camellia Rooms, where technical meetings are scheduled.

Companies interested in obtaining booth space at the exhibition can obtain

a brochure giving complete details on booth space, size, facilities available, cost of booth space and dates exhibition area will be open for display setting up, etc., by contacting R. W. Huff, Jr., NACE Exhibits Manager, 1061 M & M Bldg., Houston 2, Texas.

Houston Section Schedules Program Through January

Houston Section has scheduled its program through January 9, 1962. R. M. Robinson of Continental Oil Company is the program chairman.

June 13: Norman Hackerman of the University of Texas will discuss the First International Congress on Metallic Corrosion held at London, England, April 10-15, 1961.

August 8: O. L. Riggs of Continental Oil Company will speak on "Organic Corrosion Inhibitors."

September 12: "Do Casings Cause Pipeline Corrosion at Crossings?" by Robert J. Kuhn, consulting engineer.

October 24-26: Regional Conference, Shamrock Hilton Hotel.

November 14: Student Night. "Hydraulic Spray Application of Fiberglass Reinforced Epoxy and Polyester Resins," by Moody Adams of Matcote Company.

December 12: Ladies Night. January 9, 1962: "Corrosion Problems in Production Equipment," by F. A. Prange of Phillips Petroleum Company.

On April 11 a panel discussion was held on "The Importance of Quality Control and Record Keeping to an Effective Coating Maintenance Program." Panelists were Warren D. Palmer of Protective Coating and Engineering Service, Joseph E. Rensch of Napko Cor-

poration, L. L. Sline of Sline Industrial Painters, Inc., Dan Stauffer of Humble Oil and Refining Company, John Weis of International Minerals and Chemical Company, R. M. Robinson of Continental Oil Company was panel moderator.

Central Oklahoma Section will hear Raymond D. Daniel of the University of Oklahoma speak on "An Introduction to Metallurgy," May 1 at Oklahoma City, Adairs Tropical Cafeteria. At the same location on the section's Ladies Night, June 5, Mark Weaver of the Federal Aviation Agency will be guest speaker.

Charles M. Hudgins, Jr., of Continental Oil Company, spoke on "Corrosion Problems in the Use of Dense Salt Solutions as Packer Fluids," at Ponca City, Okla., April 10.

The March 6 meeting at Oklahoma City heard Ray M. Hurd of Texas Research Associates speak on "The Effect of Molecular Structure on Chemisorption and Corrosion Inhibition."

Permian Basin Section officers for 1961 are Chairman R. C. Booth, First Vice Chairman R. F. Weeter, Second Vice Chairman A. L. Mortimer, Secretary-Treasurer Fair Colvin and Trustee Roscoe Jarmon.

Shreveport Section held a forum on corrosion in oil and gas production equipment on March 7. The speakers and their topics were J. C. Kroner of Plastic Applicators, Inc., internal coatings; W. E. Moore of Tretolite Company, salt water disposal systems; M. J. Olive of Corrosion Control Associates, disposal systems; E. H. Sullivan of United Gas Pipe Line Company, high pressure wells. A. R. Moser of United Gas Pipe Line Company was the moderator.

G. W. Tarver of Lion Oil Company spoke on "Asphalt Coatings" at the April 4 meeting.

Greater Baton Rouge Section heard J. C. Pedarre, Jr., of the Glidden Company speak on various type coatings used in industry at the April 17 meeting.

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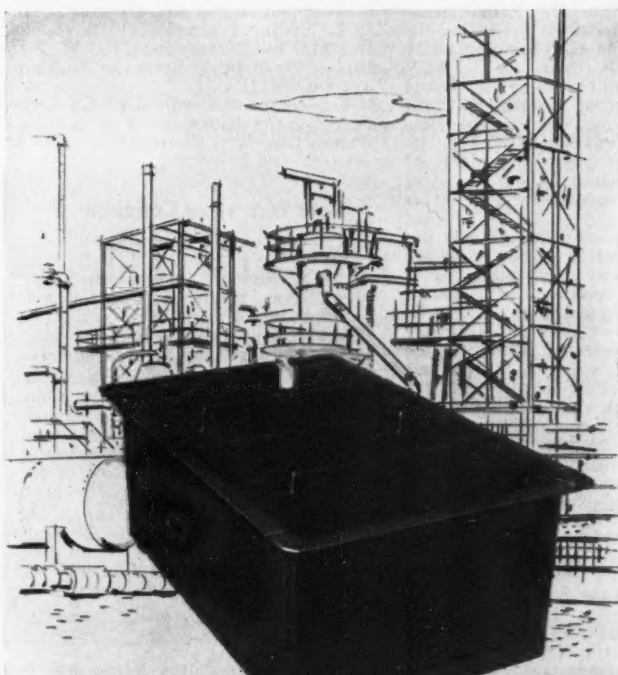
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	NO SHARES	PURCHASE PRICE	MARKET VALUE 2-24-61	VALUE INCREASE		NO SHARES	PURCHASE PRICE	MARKET VALUE 2-24-61	VALUE INCREASE
<u>COMMON STOCKS</u>					<u>DEBENTURES & PREFERRED</u>				
CIT FINANCIAL	200	14.10000	16,250.00	21,500.00					
CHASE MANHATTAN BK	100	6.56250	6,962.50	40,000.00	EL PASO NATL GAS	100	103.00000	10,500.00	20,000.00
NATL BISCUIT CO	200	14.92500	15,600.00	6,750.00	AMER TEL & TEL	100	108.75000	10,875.00	
TEX EASTERN TRANS	200	6.58750	7,400.00	8,125.00	TOTALS		21,750.00	21,375.00	20,000.00
TENN GAS TRANS	100	2.38750	2,400.00	12.50					
SOU CAL EDISON	200	12.96250	14,600.00	16,375.00	<u>GOV'T SECURITIES & SAVINGS ACCTS</u>				
4% Stock Dividend	8		58.400	58.400	<u>TREASURY SECURITIES</u>				
STD OIL of N J	200	8.67500	8,950.00	27,500.00	<u>SAVINGS & LOAN ASSO'S</u>				
PACIFIC LIGHTING	300	15.67500	16,650.00	97,500.00	20,000.00 20,000.00				
MISSOURI PUB SERV	400	8.85000	9,450.00	60,000.00	68,000.00 68,000.00				
1/4% Stock Dividend	2		47.25	47.25	TOTALS 88,000.00 88,000.00				
TOTALS		907250.00	98,893.75	8,168.75	GRAND TOTAL		199,900.00	208,268.75	8,368.75

Figure 4—NACE Investment Portfolio

Treasurer's Report—

(Continued From Page 52)

than the net from the 1960 conference, a figure estimated at \$18,000. The lower net for the 1961 conference stems primarily from the limited exhibit space available in the Statler Hilton Hotel.

Figure 3 is a condensed balance sheet at December 31, 1960. It shows total assets of \$370,773 and total liabilities and equity as the same figure. Association equity is shown as \$256,168.

Before November 18, 1960, the association's policy regarding investment of funds was to invest only in U. S. government issue securities or U. S. government agency insured bank or savings accounts. Investments of this type protected association dollars from deflation but made no provisions for protecting the money from inflation.

In 1959, the association's Finance Committee decided that some measure should be taken to protect NACE funds

from inflation. The treasurer and executive secretary were instructed to obtain proposed investment portfolios including common stock, corporate preferred stock and debentures. Proposals were obtained from two investment firms. These were presented to the Finance Committee at a meeting last November. Following the meeting, the committee recommended to the Board of Directors that NACE adopt a new investment policy that would permit investment of association funds in securities that would provide some protection from inflation as well as deflation.

A resolution passed by the Board of Directors on November 18, 1960, is as follows:

"Resolved, that association funds not needed for current operation shall be invested as follows: A minimum of 30 percent shall be invested in accounts or securities approved and/or insured by the U. S. government or an agency thereof; the remainder may be invested in a portfolio of stock and corporate bonds. The treasurer jointly with the executive secretary shall act for the association in purchasing said accounts, securities, corporate bonds and stocks and in administering the portfolio. They shall act in these matters with the advice and counsel of an investment counselor. The investment counselor shall be selected by the Finance Committee."

Acting in accordance with the resolution, the Finance Committee selected Underwood, Neuhaus & Co., Inc., an investment firm with headquarters in Houston, Texas.

Figure 4 shows the NACE investment portfolio, giving common stock purchased, number of shares purchased, purchase price and market value at close of market on February 24, 1961. The final column shows increase in value since the common stock was purchased. Incidentally, most of this common stock was purchased in mid-January.

Your executive secretary and I are quite pleased to report a net increase of \$8,168.75 in the value of the common stock purchased.

Figure 4 also shows investments in corporate debentures and preferred stock. Also shown are association funds invested in government securities and government agency insured savings accounts.

Total amount invested in the portfolio is shown to be \$199,900 with a total market value of \$208,268.75 as of February 24. We have about \$20,000 additional funds in operating bank accounts to invest in common stock and will do so when advised by our investment counselor that the time is right.

As you can see, the portfolio is quite conservative. All common stock purchased is in companies known to be

soundly operated, low-risk organizations. The stock was purchased with the expectation that their value would increase apace with inflation. Ours is a long-term investment program and does not represent any entry into the speculation field.

Treseder Is Reappointed Publications Chairman

R. S. Treseder of Shell Development Co., Emeryville, Cal., has been re-appointed chairman of the NACE Publications Committee and J. P. Barrett of Pan American Petroleum Corp., Tulsa, Okla., appointed vice chairman of the committee by NACE President E. C. Greco.

Committee members re-appointed by Mr. Greco are R. D. Misch of Argonne National Laboratory, Lemont, Ill., Miss Ivy M. Parker of Plantation Pipe Line Co., Atlanta, Ga., C. G. Munger of Amercoat Corporation, South Gate, Cal., J. E. Loeffler of Thornhill Graver Co., Houston, Texas, J. L. Battle of Humble Oil & Refining Co., Houston, Texas, and Fred M. Reinhart of the National Bureau of Standards, Washington, D. C.

Two subcommittees of the Inter Society Corrosion Committee, which has been inactivated, have been transferred to NACE's

Data Wanted on Corrosion Caused by Bird Droppings

The National Pest Control Association wants information on the nature and monetary value of defacement and corrosion of materials caused by bird droppings.

The association is preparing a manual of bird management. One major purpose of the manual would be to distribute information on methods of preventing corrosion or defacement by bird droppings.

Any information pertaining to the above problem should be sent to Philip J. Spear, Technical Director, National Pest Control Association, 250 West Jersey St., Elizabeth, N. J.

Publications Committee. These will continue their same functions under the Publications Committee as was done under ISCC. They are the Subcommittee of Overseas Correspondents and the Subcommittee on Standard Definitions and Terminology.

Proposed revision of the scope of activities for the Subcommittee of Overseas Correspondents, as proposed by the chairman, Hugh P. Godard, are as follows: (1) to maintain correspondents in overseas countries active in the corrosion field, (2) to obtain an annual report or summary of corrosion activity in the country of each correspondent, (3) to assist overseas corrosion workers in making suitable contacts with their counterparts in North America and (4) to assist North American corrosion workers in making suitable contacts with their counterparts abroad.

More than 125,000 two-way radio transmitters are in operation by utility companies in this country.

The 1961 Western Region Conference will be October 4-6 at the Hotel Multnomah, Portland, Oregon.



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Joint wrapping of mill coated pipe is easy, fast and sure with Arno Pipe-Wrap Tape. Its inert polyethylene backing is moisture proof, non-conductive and resistant to soil acids and alkalis. Tough and stretchy. High-tack adhesive. Write for information and free test sample.

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MANUFACTURERS AGENTS WANTED FOR SOME SELECTED AREAS

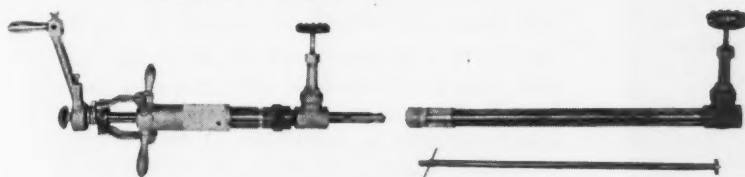
Now! CPS Platinum-Titanium Anodes New Solution to Heater Treater Corrosion

COMPLETE PROTECTION

Titanium has the unique ability to effectively insulate itself and resist corrosion in electrochemical circuits by absorbing oxygen at its surface. When titanium is coated with a layer of platinum, performance is equal to that of a solid platinum anode but at a fraction of the cost.

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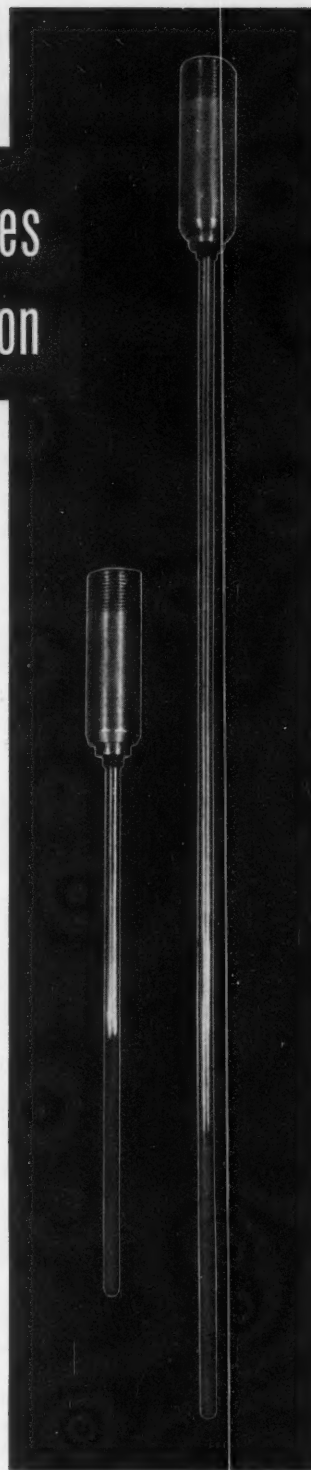
CPS's new small Platinum-Titanium anodes are especially valuable in Heater Treaters, Salt-water Vessels, Heat Exchangers, Water Lines (internal), Pump Manifolds and Process Equipment where space, temperature and corrosive gases make conventional anodes questionable, impractical or difficult to install.



NO DOWN TIME

By using the simple Hot Tapping Tool and Lubricator, hot taps and anode installation can be made without taking existing vessels out of service.

Let one of our 20 experienced engineers make recommendations for specific installations of CPS Platinum-Titanium anodes. Call, wire or write the CPS office nearest you.



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Facts about pickling acid inhibitors

Nearly 40 years ago Amchem developed the first pickling acid inhibitor—RODINE—and with it revolutionized acid pickling. Only a few of the steel mills of the time believed that the addition of less than one percent RODINE to a sulfuric acid pickling bath could save substantial amounts of acid and metal, while increasing the life of the bath. Today there is no mill chemist who does not know about RODINE and its proven performance in eliminating waste of valuable metal and acid, and its ability to pay for itself through the savings thus gained.

In the past few years much attention has been focused on the use of wetting agents to accelerate pickling. But the fact remains that pickling cycles cannot be reduced by the use of wetting agents alone without severe overpickling problems. Wetting agents do help the acid run off surfaces removed from pickle baths, and, in so doing, reduce carry-over of acid into the rinse.

Wetting agents should not be confused with inhibitors to protect the metal and save acid wasted in pitting it. They should not be expected to miraculously speed the removal of scale, even at the expense of wasting the

metal. However, the *proper* combination of *real inhibitor* plus correct wetting agent can have beneficial effects on pickling practices.

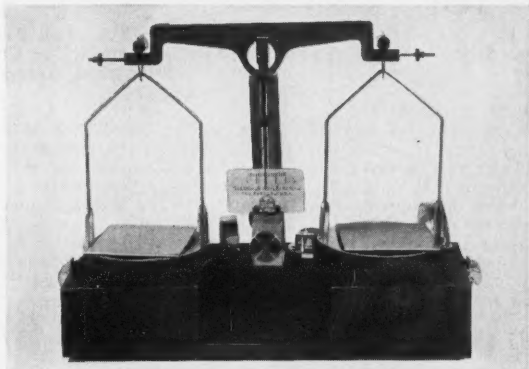
Only a true inhibitor such as RODINE can offer steel producers solid advantages in pickling. Baths can be operated longer and less acid is required to keep them at desired concentration. Costs of charging and cleaning the bath are reduced, less handling and storing of acid is required. A RODINE bath produces far fewer rejects—steel emerges with uniformly smooth, bright clean surfaces, free of pits, blisters and smut.

When an Amchem Technical Representative enters your pickle house, you can be assured of experienced assistance in improving your pickling. He will recommend the proper RODINE to 1) prevent needless consumption of acid after scale removal, 2) prevent smutting, pitting and overpickling, 3) produce a stable, free-rinsing foam blanket, 4) improve rinsability and reduce carry-over, and 5) produce a brighter, cleaner surface. Only the Amchem Representative can do this for you because he has at his command the most widely diversified and accepted line of real inhibitors and correct wetting agents available.

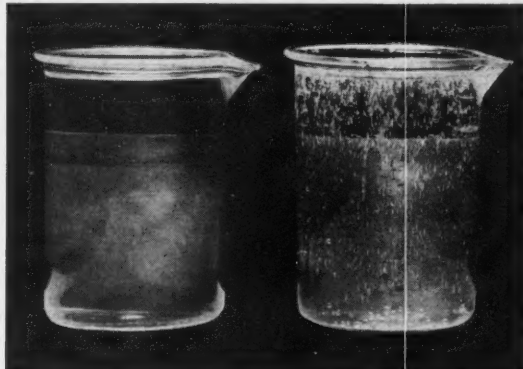
Since the early days of pickling acid inhibitor development, scientists in the Amchem-Metal Protection Laboratories have constantly studied methods to make the RODINES stronger, more effective and more economical to use. The RODINES of today, as of 40 years ago, are in a class by themselves, have devel-

oped a reputation as *the international standard* in acid pickling inhibitors. The fruit of these years of laboratory research and experience in a highly specialized field, and the assistance of Amchem's trained field representatives—specialists in acid pickling techniques—are at your disposal for the asking.

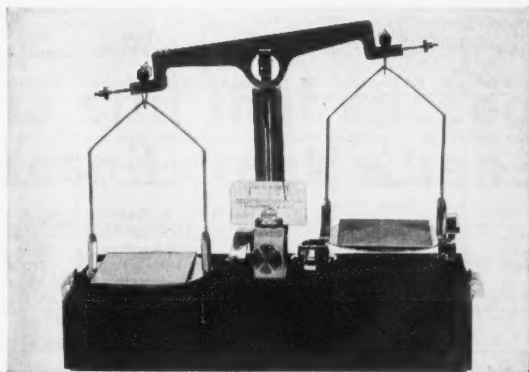
How Rodine Retards Acid's Attack on Metal



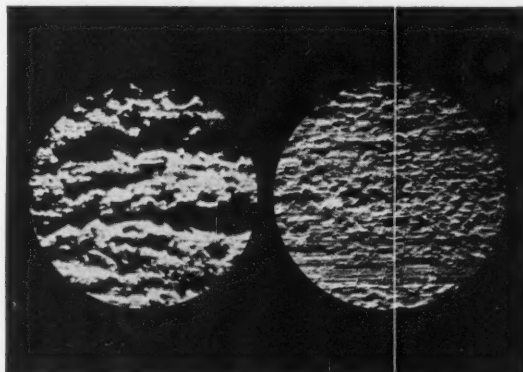
The photographs and microphotographs displayed on this page represent a graphic description of results demonstrating the effectiveness of RODINE in retarding the attack of acid on the metal. **NO WEIGHT DIFFERENCE**—two identical panels of low-carbon steel are shown being weighed here. They balanced the scale.



RODINE MINIMIZES ACID ATTACK—Each descaled panel was placed in a beaker containing 10% by volume of 66° Bé sulfuric acid of 160°F. The acid in the right-hand beaker was uninhibited. Acid in left-hand beaker was inhibited with RODINE 82, 1/4% by volume of the concentrated acid. There was little or no hydrogen evolution in this beaker . . . RODINE retarded the attack of the acid on the base metal.



RODINE SAVES METAL—Both descaled panels were removed from the acid pickle solutions after 5 minutes. The one pickled in the uninhibited acid had lost 1.4% of its original weight. The one pickled in the RODINE-inhibited acid had lost only 0.001% of its original weight. This represents a saving of 26 lb. of steel for each ton pickled; and a simultaneous saving of nearly 50 lbs. of 66° Bé sulfuric acid when RODINE is used to inhibit the acid.



EFFECT OF UNINHIBITED ACID ON THE PANEL—This microphotograph of the low-carbon sheet steel pickled in the uninhibited acid shows deep pits and the crystalline character of the surface after 5 minutes in the solution.

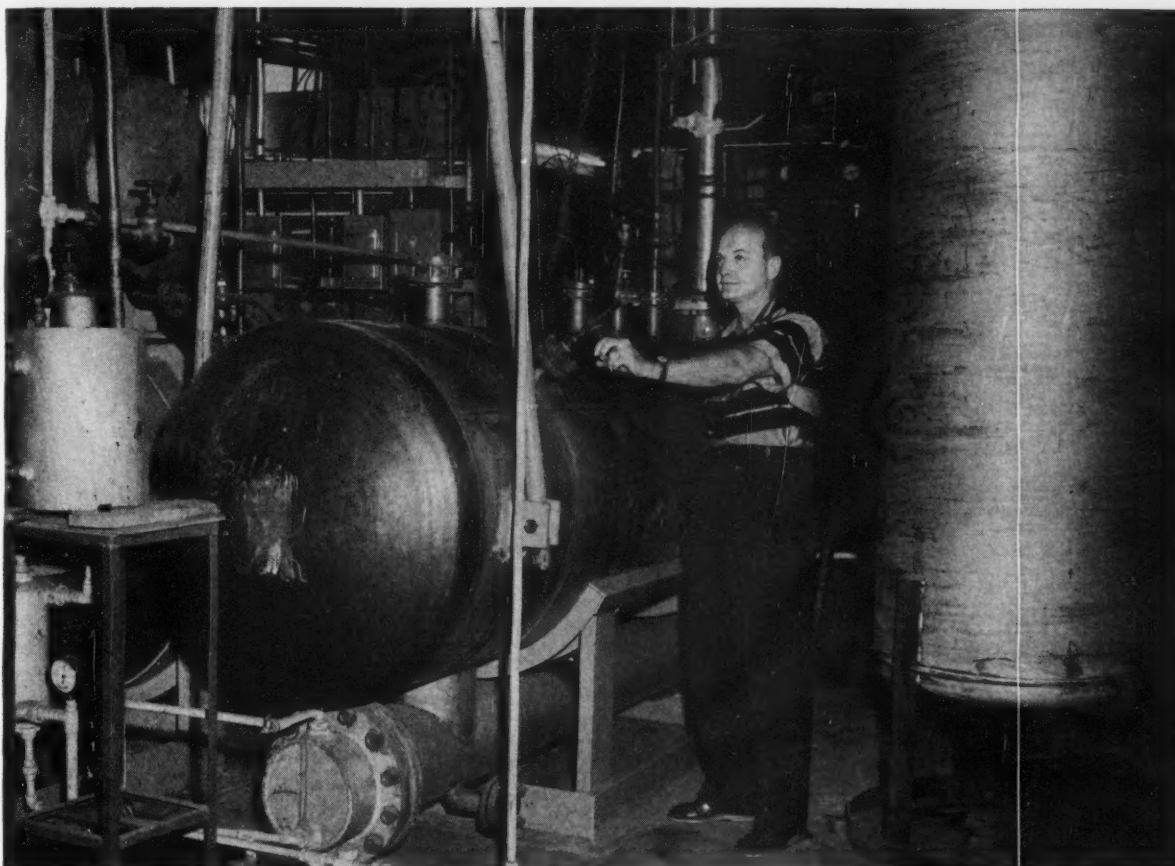
EFFECT OF RODINE-INHIBITED ACID ON THE PANEL—This panel was pickled for 5 minutes in the RODINE-inhibited acid, then microphotographed. Only scale pockets and roll marks are visible; no pitting of the low-carbon sheet steel occurred.



RODINE

Amchem and Rodine are registered trademarks of **AMCHEM PRODUCTS, INC.** (Formerly American Chemical Paint Co.)

AMBLER, PA. • Detroit, Mich. • St. Joseph, Mo. • Niles, Calif. • Windsor, Ont.



Stress-corrosion cracking is prevented by the use of Monel alloy for this chloride still at Halocarbon Products Corporation, Hackensack, N. J. Still separates intermediate required in the production of chlorofluorocarbons. It was fabricated by Stainless & Steel Process Equipment Company of Whippany, New Jersey.

The still that succeeded—because Monel doesn't crack when stressed in chlorides

This is a Monel* nickel-copper alloy still with 2½ years of chloride separation behind it, and many more ahead.

The previous still developed stress-corrosion cracks and failed in just about a year... even though made of an alloy with a good record of resistance to generalized chloride attack.

An insidious form of corrosion

Stress-corrosion accounts for many somewhat mysterious premature failures that have occurred in equipment handling chlorides.

Fortunately such failures can be prevented. First step is to pinpoint the conditions in your own plant that favor stress-corrosion attack. In this

respect, the rule-of-thumb guide at the right may prove helpful. Second step is to use high-nickel materials, such as Monel alloy, for endangered equipment.

Laboratory tests show that resistance to cracking in chloride solutions increases with nickel content. Alloys containing at least 42% Nickel appear to be immune to stress-corrosion cracking under most conditions.

Monel nickel-copper alloy also provides outstanding resistance to generalized corrosion by chlorides. What's more, Monel alloy is readily available and easily fabricated and welded... entirely practical and widely used for pumps, piping, coils, pressure vessels and other equip-

ment. For expert advice regarding specific applications, write:

*Inco trademark

HUNTINGTON ALLOY PRODUCTS DIVISION
The International Nickel Company, Inc.
Huntington 17 West Virginia

What every engineer should know about Chloride-Ion-Stress-Corrosion Cracking

Cracks . . . large, straight or branched, usually transgranular but may be intergranular.

Causes . . . It is best explained as an electrochemical mechanism with crack initiation being related to the available oxygen, specific concentrations of the chloride ion, and the stress level.

Potential . . . Stress-corrosion cracking has been observed in engineering materials that have been cold worked, rolled, welded, periodically wetted and dried. It may occur at stresses as low as 2000 psi; water containing as low as 50 parts per million chloride; at temperatures as low as 100° C.

MONEL®



Rolland McFarland, Jr.
President



C. G. Munger
Vice President



C. G. Gribble, Jr.
Treasurer

McFarland, Munger and Gribble Nominated as 1962-63 Officers

Nominations of candidates for election to the highest offices in NACE have been received from the nominating committee. Officers elected will serve for the 1962-63 term. Rolland McFarland, Jr., is nominated for president, C. G. Munger for vice president and C. G. Gribble, Jr., for treasurer.

Nominated for terms on the Board of Directors are W. H. Burton to represent corporate members and O. H. Fenner and M. E. Holmberg to represent active members. These three nominations to the Board of Directors are for three-year terms, beginning March 23, 1962.

Nominations made by the committee can be supplemented by nominations from active NACE members in accordance with Paragraph 3 of Section 3, Article VIII of the NACE Articles of Organization which states as follows:

"Not later than a date to be fixed as provided in Section 5 of this Article, (Article VIII). The Secretary shall inform all members of the Association, by publication or otherwise, of the list of nominees reported to him by the Nominating Committee; and at any time prior to a later date, to be fixed as provided in Section 5 of this Article, additional nominations may be made by petition forwarded to the Secretary and signed by at least twenty-five (25) active mem-

bers. Any such nominees for the office of President, Vice President or Treasurer shall qualify as provided in the first paragraph of this section."

As indicated by the schedule published on this page, active members have until June 12 to submit the names of additional nominees by petition. Voting will be by letter ballot in September. Deadline for votes to be in Central Office will be September 26. Tellers will have until November 1 to prepare their report of the ballot count.

BIOGRAPHIES of NOMINEES

ROLLAND MCFARLAND, Jr., secretary and technical director of the Hils-McCanna Company, Chicago, Ill., has been engaged in design and application of pumps, valves and allied equipment for over 20 years. An NACE member since 1948, he has been chairman of Technical Committee T-6A and is currently vice president of NACE. He has served as an NACE director representing active membership. He also is a member of AIChE, ACS and ASM and is a graduate of Armour Institute of Technology's school of chemical engineering.

C. G. MUNGER, vice president of Amercoat Corporation, South Gate, Cal., has been a member of NACE since 1947 and a member of the Los Angeles Section since its organization. Affiliated with Amercoat and its parent company since 1935, he has been active in NACE work, written several technical papers on corrosion control and coating materials and has served as a member of NACE's Board of Directors.

C. G. GRIBBLE, Jr., district manager for Metal Goods Corporation, Houston, Texas, was elected treasurer of NACE for 1961-62 and has been renominated for that office. A corporate member of NACE since 1954 and a member since 1948, his NACE activities have included membership on the Board of Directors as representative for corporate members, local arrangements committee chairman for the 1952 Annual Conference in Galveston, co-chairman for exhibits at the 1957 Conference in St. Louis and chairman of the Houston Section.

W. H. BURTON, an NACE member since 1953, is materials consultant in charge of the Materials Engineering and Corrosion Section of the Engineering Department of Allied Chemical Corporation's General Chemical Division, Camden, N. J. He has been with the company for over 27 years. His NACE activities include chairman of Technical Committee T-5 on Corrosion Problems in the Process Industries and membership on the Philadelphia Section's governing board. He also is NACE's representative on the ASA. He has an MS in industrial chemistry and an ME in mechanical engineering from Stevens Institute of Technology. He is a member of the High Alloy Steel Committee of the Welding Research Council and the AEC Welding Forum.

O. H. FENNER, a member of the research staff at Monsanto Chemical Company, St. Louis, Missouri, has been production supervisor, area supervisor, project supervisor, and supervising engineer with the firm since he joined it in 1934. Included in his NACE activities are organization of the Greater St. Louis Section, co-editor of the St. Louis Section monthly "Corrosion Topics," chairman of T-5D-7 on Engineering Design of Plastic Materials of Construction for the Chemical Industry and membership on other NACE technical committees. He has a BA from Washington University.

M. E. HOLMBERG, a metallurgical consultant of Houston, Texas, joined NACE during its organization in 1945. For 15 years he was associated with Phillips Petroleum Company, Bartlesville, Oklahoma, where he was manager of the test division. Since 1951, he has operated his own business as a metallurgical consultant in Houston, working on metallurgical and corrosion problems related to the oil and petrochemical industries.

Only Corporate Member Directory to Be Published

The NACE Board of Directors decided to publish in CORROSION only the Corporate Member Directory in the future. This directory will appear in the June, September and December issues this year.

The other two directories normally published in the magazine four times each year will be printed and distributed by other means. These are the directories of region and section officers and technical committee officers.



Burton



Fenner



Holmberg

OFFICIAL REPORT NOMINATING COMMITTEE

The Nominating Committee at its March 17 meeting selected the following nominees for officers and directors for terms beginning March 23, 1962:

For President:

Rolland McFarland, Jr., Hills-McCanna Company, Chicago, Illinois.

For Vice President:

C. G. Munger, Amercoat Corporation, South Gate, California.

For Treasurer:

C. G. Gribble, Jr., Metal Goods Corporation, Houston, Texas.

For Director to represent corporate membership:

W. H. Burton, Allied Chemical Corporation, Camden, New Jersey.

For Director to represent active membership (two to be elected):

**O. H. Fenner, Monsanto Chemical Company, St. Louis, Missouri.
M. E. Holmberg, consultant, Houston, Texas.**

Schedule of Dates for Nomination and Election of National Officers and Directors for Terms Beginning March 23, 1962.

ACTIVITY	DATE TO BE COMPLETED
Formation of Nominating Committee (completed)	March 12, 1961
Nomination of Candidates and report to the Secretary (completed)	April 1, 1961
Publication of Nominating Committee report	May 1961 issue of CORROSION
30 to 65 days for members to prepare and file nominations by petition	June 12, 1961
Preparation and mailing of letter ballots to NACE members	July 24, 1961
Period allowed for members to return letter ballots	September 26, 1961
Period allowed to count ballots and prepare report by tellers	November 1, 1961
General Business Meeting	March 21, 1962

List of Members Eligible for Nomination to the Office of President, Vice President or Treasurer of NACE for the Term Beginning March 23, 1962.

J. P. Barrett, J. L. Battle, H. L. Bilhartz, J. D. Bird, E. F. Bladholm, R. A. Brannon, E. G. Brink, H. R. Brough, J. A. Caldwell, J. Pat Casey, Jr., W. R. Cavanagh, Stephen P. Cobb, F. E. Costanzo, Stephen D. Day, Irwin C. Dietze, L. B. Donovan, J. S. Dorsey, W. F. Fair, Jr., M. G. Fontana, L. W. Gleekman, C. G. Gribble, Jr., H. F. Haase, Norman Hackerman, H. L. Hamilton, Derk Holsteyn, A. N. Horne, R. B. Hoxeng, L. A. Hugo, H. A. Humble.

V. N. Jenkins, T. F. P. Kelly, W. J. Kretschmer, Frank E. Kulman, R. E. Kuster, F. L. LaQue, C. P. Larrabee, R. J. Law, R. H. Lynch, R. McFarland, Jr., George B. McComb, F. J. McElhatton, T. J. Maitland, V. V. Malcom, T. P. May, R. B. Mears, E. F. Moorman, C. G. Munger, A. R. Murdison, W. R. Myers.

E. P. Noppel, G. R. Olson, Miss Ivy M. Parker, R. K. Pierce, W. F. Rogers, J. E. Rench, L. F. Scherer, H. W. Schmidt, Edward L. Simons, A. D. Simpson, Jr., A. B. Smith, D. E. Stearns, A. L. Stegner, W. H. Stewart, Fred D. Stull, E. H. Tandy, R. S. Treseder, H. C. Van Nouhuys, E. D. Verink, Jr., Aaron Wachter, H. E. Waldrup, L. C. Wasson, T. R. B. Watson, John B. West, F. L. Whitney and Guy F. Williams.

* Eligible for nomination for president only.

Any Active Member in good standing is eligible for nomination as a Director to represent the Active Membership of the Association, and any Representative of a Corporate Member in good standing is eligible for nomination as Director to represent the Corporate Members of the Association, except the following who are not eligible for nomination as an elected director for the term beginning March 23, 1962, because of the time limitation in Section 5, Article IV of the Articles of Organization.

represent the Active Membership of the Association, and any Representative of a Corporate Member in good standing is eligible for nomination as Director to represent the Corporate Members of the Association, except the following who are not eligible for nomination as an elected director for the term beginning March 23, 1962, because of the time limitation in Section 5, Article IV of the Articles of Organization.

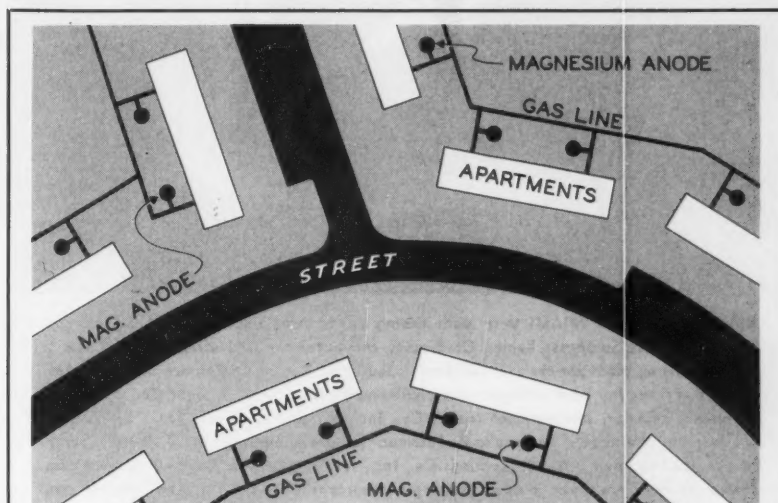
List of Members not Eligible for Nomination as Director for Term Beginning March 23, 1962.

J. B. Barrett, George E. Best, J. D. Bird, E. F. Bladholm, R. A. Brannon, E. G. Brink, F. E. Costanzo, J. S. Dorsey, L. W. Gleekman, H. P. Godard, E. C. Greco, C. G. Gribble, Jr., H. L. Hamilton, Frank E. Kulman, R. E. Kuster, R. McFarland, Jr., T. J. Maitland, E. F. Moorman, J. E. Rench, E. L. Simmons, A. B. Smith, A. L. Stegner, Fred D. Stull, E. H. Tandy, R. S. Treseder, L. C. Wasson, T. R. B. Watson, J. B. West, L. L. Whiteneck and Guy F. Williams.

Mark F. Adams Appointed NACE Education Chairman

Mark F. Adams of the State College of Washington, Pullman, Wash., has been appointed chairman of NACE's Education Committee by President E. D. Greco.

President Greco also re-appointed the following to membership on the committee: Norman Hackerman of the University of Texas, Austin, Harry J. Keeling, consulting engineer of Los Angeles, Cal., Frank B. Burns of General Asphalts, Inc., Wynnewood, Okla., Aaron Wachter of Shell Development Co., Emeryville, Cal., and J. J. Harwood of the Department of Navy's Office of Naval Research, Washington, D. C.



LEAKS IN GAS LINES STOPPED AT HOUSING DEVELOPMENTS

The management of three Ohio housing developments was faced with an increasing number of leaks in the gas lines serving the apartments. External corrosion was found to be the cause, and CSI was awarded a cathodic protection contract on a bid basis.

To stop the corrosion, CSI engineers installed 17-pound magnesium anodes. The anodes project a protective electrical current onto both the 2-inch lines leading into the individual apartments and the larger distribution lines. More than 350 anodes, pre-packaged with backfill in cloth bags, were used. Protection was designed for 10 years.

CSI furnished the anodes plus all necessary labor and equipment—augers, ditchers, etc. Some anodes were installed under concrete and blacktop. In all cases, installations were made to the inspectors' satisfaction.

It will pay you to check with CSI engineers. They offer expert engineering and installation services—to stop corrosion on pipelines, gas well casing, tank bottoms, etc. Also quality supplies for both rectifier and magnesium anode installations.

CSI

Cleveland 13, Ohio
1309 Washington Ave.
Tel. CHerry 1-7795

**CORROSION SERVICES
INCORPORATED**

General Office: Tulsa, Okla.
Mailing Address:
Box 787, Sand Springs, Okla.
Tel. CIRCLE 5-1351

Southeast Region



PLANS FOR SUNNY MIAMI were made during sub-freezing weather at the Buffalo conference by these Southeast Region Conference committeemen and officers. Shown left to right discussing plans for the Nov. 27-Dec. 1 Southeast Region Conference in Miami, Fla., are J. B. Prime, Jr., local arrangements chairman, Florida Power & Light Co., T. P. May, conference director, International Nickel Co., Inc., Wrightsville Beach, N.C., E. W. Seay, Jr., program chairman, Chesapeake & Potomac Telephone Co., and H. T. Rudolf, Southeast region chairman, Atlantic Coatings Co., Inc., Jacksonville, Fla. Other conference committee chairmen are shown in accompanying photographs. They are J. J. Abril, finance committee, Florida Power & Light Co., Miami; N. H. Bollinger, Jr., publicity committee, Peoples Gas System, North Miami, B. M. Botsford, registration committee, Southern Bell telephone and Telegraph Co., Miami, J. G. Burns, printing committee, Florida Power & Light Co., Miami, and C. H. Montague, publicity committee, Peoples Gas System, North Miami.

President Greco to Speak At Southeast Conference

NACE President E. C. Greco will give the opening address at the Nov. 27-Dec. 1 Southeast Region Conference to be held in conjunction with the Florida General Conference. The meeting will be held at the Key Briscayne Hotel in Miami.

Accompanying photographs are of the conference committee chairman and members who are completing arrangements for the technical program and local arrangements.



Abril



Bollinger



Botsford



Burns



Montague

Atlanta Section Program Planned Through December

Program plans through December have been made by the Atlanta Section. The May 9 meeting has been scheduled on protective coatings. Remainder of the programs are as follows:

June 12: Program on electrochemical fundamentals.

October 9: Section will be host for Georgia Electrolysis Committee, which will hold a meeting on October 10. The October 9 meeting will be on problems in corrosion coordination.

December 4: Corrosion problems of nuclear energy installations.

At the April 10 meeting, B. Husock spoke on cathodic protection for underground corrosion problems. This meeting was in connection with the Georgia Electrolysis Committee meeting on April 11.

Section Officers Elected

Atlanta Section officers elected for 1961 are Chairman Emmitte P. Tait, Vice Chairman James W. Joyner, Secretary-Treasurer Edwin M. Steinman and Assistant Secretary-Treasurer James R. Stem.



SECTION CALENDAR

May

- 8 Kansas City Section.
- 8 Greater St. Louis Section.
- 8 Central Oklahoma Section.
- 8 North Texas Section.
- 8 Eastern Wisconsin Section. Corrosion Resistance of Copper Alloys and Aluminum Alloys, by Wilson Lynes of Revere Copper and Brass, Rome, N. Y.
- 9 Twin City Section.
- 9 Permian Basin Section.
- 9 Houston Section.
- 9 San Francisco Bay Area Section.
- 12 Rocky Mountain Section.
- 16 Cleveland Section.
- 16 Chicago Section. New Coating Resins to Combat Corrosion.
- 18 Vancouver Section.
- 18 Alamo Section.
- 19 Kanawha Valley Section. Roundtable Discussion led by George C. Cox and A. L. Hamstead. To be at Charleston.
- 22 Tulsa Section.
- 24 Wilmington Section. Guest speaker W. Z. Friend of International Nickel Co., Inc.
- 30 Panhandle Section.
- 30 Southwestern Ohio Section. Guest speaker J. S. Long of University of Louisville. To be held at Cincinnati, Ohio.
- 31 Philadelphia Section.

June

- 13 Houston Section. Report on First International Congress on Metallic Corrosion held in London, by Norman Hackerman, University of Texas.

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Teenage Student Wins Awards With Corrosion Display-Project

Pieter Van Deusen, a 15-year old high school student of Plainfield, N. J., has won several prizes and awards with his project report and display entitled "Coatings Against Corrosion."

He won first prize in the Senior Boys Division of the Watchung Hills Regional Schools Science Fair held in March. His display was the only one of its type exhibited at the fair.

At the Central Jersey Science Fair held March 29 at Rutgers University, his corrosion project and display won First Honorable Mention and the Air Force Award for Aerospace Sciences.

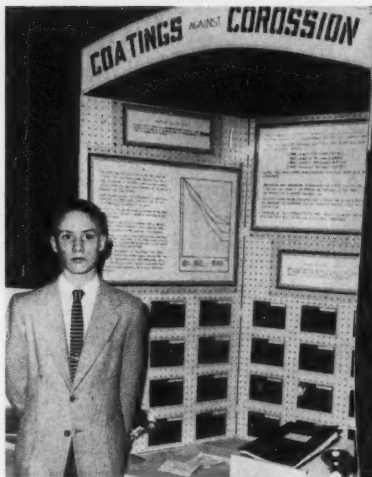
Pieter began work on his corrosion display more than a year ago. He wrote NACE Central Office for information and materials to begin his work. This included several NACE Technical Committee Reports.

His project included a 47-page typed report of his coating tests which included a spot test and a water bath exposure. The statement of his project problem is given in the report as follows:

"To find the best possible economical paint film thickness by using a spot test and water bath and to compare the results of these tests with the results of similarly coated panels hung in an industrial atmosphere for an extended period of time. The spot test will be conducted using xylene, 5 percent solution hydrochloric acid and 5 percent solution caustic soda. The water bath test will consist of placing the test panels in water maintained at a given temperature."

A secondary problem of the project was to decide which of three surface preparations were the best. The three types were mill scale steel plate, shot blasted steel plate and bright steel plate.

Pieter's typed report included definitions of terms, introduction pages on coatings, a detailed record of the steps in his test procedure and the conclusions he made from his test data.



CORROSION PROJECT on coatings won this 15-year old high school student several prizes and awards. He is Pieter Van Deusen, a tenth grade student at Watchung Hills Regional High School in Plainfield, N. J.

Also included in the report was background information on the importance of corrosion control to industry, a bibliography and a list of materials used in the project.

Personnel at NACE Central Office who saw a copy of Pieter's typed report were impressed by the detailed work this young man had done on the corrosion project.

Pieter is a tenth grade student at Watchung Hills Regional High School and lives at Old Sterling Road, Plainfield, N. J.

in each case is considered to be at an optimum level so that scheduling can be done three months in advance. Under the direction of Fred M. Reinhart, the Editorial Review Subcommittee with its 27 members has been doing an excellent job of improving the technical standard of CORROSION and has been efficient in processing papers to facilitate early publication.

Editorials in CORROSION have been well received and have provoked some worthwhile controversy in several instances. The "Focus" idea of combining articles on a single general subject in the Technical Topics was tried several times during the year and was thought to be of benefit to readers and advertisers.

As yet, no one has been appointed to the position of associate editor as authorized by the Board of Directors a year ago.

Circulation had a slight drop (0.7%) in total paid circulation; however, the non-member subscription continued to increase at a healthy rate (10.6%).

Advertising revenue increased 17.3%, due primarily to the rate increase put into effect during the year. The 1961 advertising revenue is expected to be about the same as the 1960 figure.

Abstract services have continued to improve in quality and coverage through efforts of the Abstract Subcommittee working with the Houston office. At present, there are 26 abstracting sources, giving a world-wide coverage.

The 1956 Bibliographic Survey was published in late 1960. Initial sales have been encouraging. A new production system and format were used which should allow more efficient production in the future. It has been decided to combine the 1957 and 1958 surveys; this will hasten achievement of the goal of having the Bibliographic Survey issued with only a two-year lag, the minimum considered feasible.

Abstract Card Service subscribers decreased slightly from 69 in 1960 to 63 in 1961. Because of the declining interest over the years in this service, serious thought is being given to supplanting it with an abstract journal published 6 or 12 times a year.

Other publications issued during the year included four monograph-type publications which are selling well: (1) Residual Oil Ash Corrosion Problem: Bibliography for Residual Fuel Oil Ash Corrosion, (2) High Purity Water Corrosion of Metals, (3) Proceedings: Ohio State Short Course on Process Industry Corrosion and (4) Report on Stress Corrosion Cracking of Austenitic Chromium-Nickel Stainless Steels, published in cooperation with ASTM.

Thanks to increased revenue in 1960 resulting from advertising rate increases and from increased membership dues, publication activities had a satisfactory financial year. In view of the general business picture in 1960, it is noteworthy that we were able to increase our publication activities to the members in the form of more technical material in CORROSION and increased number of monograph type publications.

I would like to acknowledge the contributions of Dr. Ivy Parker, T. J. Hull, N. E. Hamner and individual members of the Committee and of the Houston staff in giving NACE a successful publications year.

R. S. Treseder
Chairman

Publication Committee Activities Summarized in 1960-61 Report

Following are highlights of the Publications Committee's activities during the year, March, 1960, to March, 1961.

Membership

T. P. May and A. W. Tracy resigned their memberships at the beginning of the year. C. G. Munger was appointed to the committee to serve as Finance Subcommittee Chairman.

Meetings

In addition to two meetings held during the Dallas Conference, a meeting was held in Houston on January 16, 1961. Minutes of these meetings are on file in the Central Office.

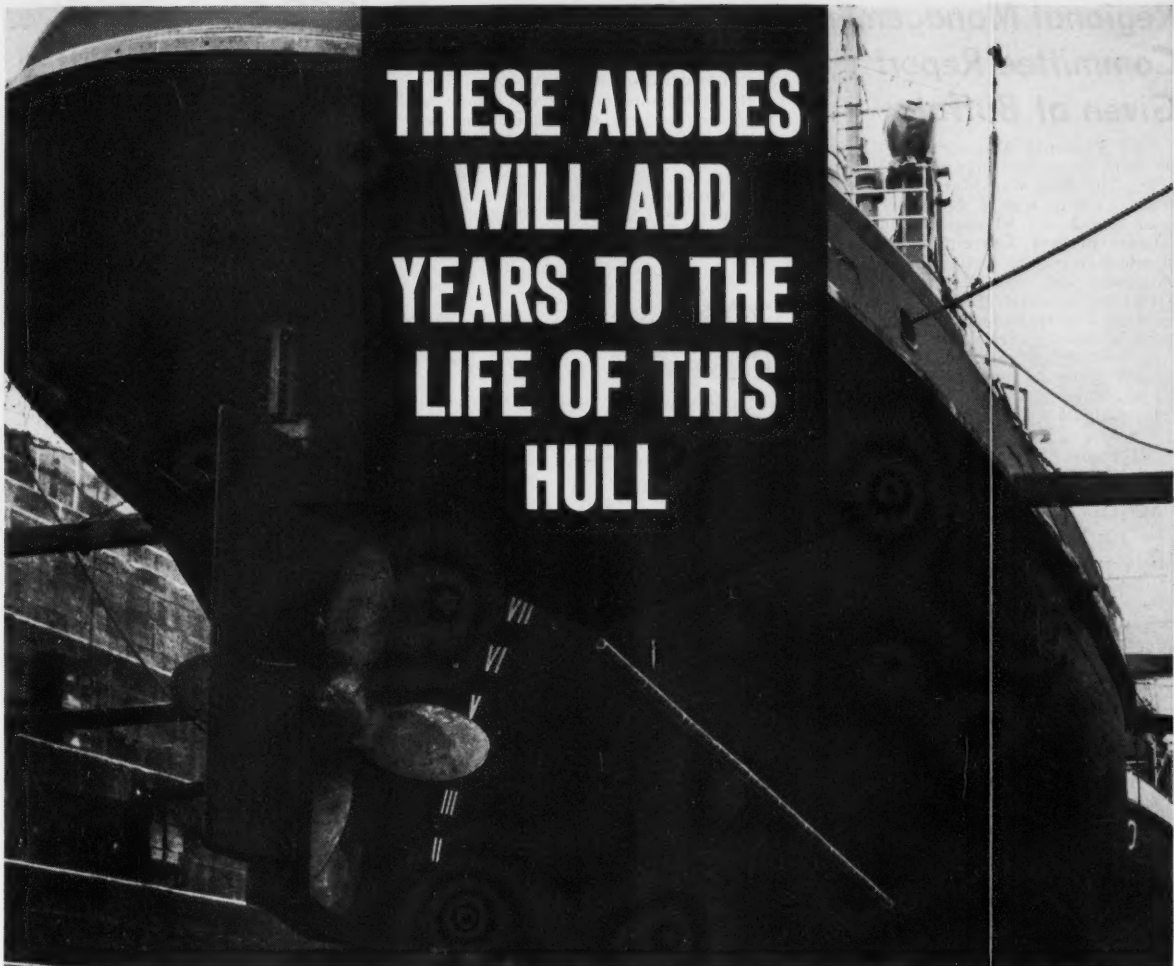
Corrosion

Editorial changes in CORROSION begun in January, 1960, have been well accepted by the membership. During the year, efforts have been directed toward improving both the technical content and the appearance of the magazine. Quantity of technical information supplied the readers was as follows:

Section	Pages	% Increase Over 1959
Technical	644	4
Technical Committee	9	55
Technical Topics	130	50
Record and Report	94	40
Abstracts	130	13
Total Editorial	1199	6

Thus, while maintaining a steady growth in the Technical Section, there has been a large growth in the news-technical type material. This is in line with the policy adopted in 1959 of working toward creation of two magazines—one a standard technical journal and the other a news type of technical magazine aimed at providing application type information. The actual physical separation of the two magazines is under active consideration by the Publications Committee.

The supply of technical material for both the Technical Section and Technical Topics has been quite adequate. Backlog of material available for publication



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at the end of their calculated life which can be made to coincide with scheduled dry docking. Cathodic protection with ZINC provides a practical effective solution to the costly problem of hull maintenance.

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Regional Management Committee Report Given at Buffalo

The Regional Management Committee held three meetings during the past year. The first was March 15, 1960, in Dallas, Texas, with J. B. West as chairman and some 50 region and section officers present. Current procedure for reimbursements to sections for operating expenses was considered satisfactory. Members' optional choice of section affiliation was recommended. The present section activity reporting system also was considered satisfactory. Also discussed were section meeting publicity, membership, package registration and fellowship hour activities.

On May 25, 1960, the committee met in Houston, Texas. The importance of good communications between section officers and association headquarters (and regional directors) was emphasized. Steps were suggested and adopted to improve these relations.

The committee recommended that package registration be modified for greater flexibility.

The committee favored re-examination and revision of the association's Articles and By-Laws to provide for formation of foreign sections.

Consideration also was given to the possibility of improving the reimbursement procedure, but no changes were recommended.

The third meeting of the committee was held in Chicago on November 17, 1960. Although we had established that the State Department looked favorably on formation of foreign sections, the committee decided that organizational factors would be too complicated in view of unsettled political and economic conditions abroad and unanimously agreed that regions and sections should not be established at this time outside Canada, Mexico and the United States as now provided. Changes were recommended to eliminate the "continental" restriction to permit formation of sections in the State of Hawaii.

The committee recommended that appropriate changes be made in our organization to provide members the privilege of affiliation with a section other than that of their residence if they so desire. It also was pointed out to the Board of Directors that members outside an established section or region now can affiliate with any section or region of their choice and that possibly this privilege should be restricted to members residing in Canada, Mexico and the United States only. It should be noted that members outside Canada, Mexico and the United States now have all privileges of membership except that of voting at the section and regional level. (The latter is available on request.) A limited survey indicated that many scientific societies have large foreign memberships with no provision for region or section affiliation.

After lengthy consideration, the committee recommended that no changes be made in the reimbursement procedure.

In connection with strict uniformity of region and section organization and rules, the consensus was that some degree of local option was desirable, within the general rules and framework of the association, to provide the flexibility necessary for our different geographical

areas and diverse problems.

Many of the items mentioned above were referred by the Board of Directors to the Policy and Planning Committee for consideration and advice.

By correspondence, attempts have been made to improve communications with sections. Continued study of and reference on the part of region and section officers to the manuals provided have been emphasized repeatedly. Section and regional meetings have maintained the improved objective of recent years.

W. W. Fair, Jr.
Chairman

20-Year ISCC History Presented in Report

Inter Society Corrosion Committee

At its annual meeting in Buffalo on March 16, 1961, the Inter Society Corrosion Committee voted to disband and requested that the National Association of Corrosion Engineers, accept the responsibility for two functions which the committee recommended be continued: maintenance of international relations in the corrosion field and standardization of corrosion terminology.

The committee was formed in 1940 as the American Coordinating Committee on Corrosion to collect and coordinate corrosion information and to promote the publication of a journal devoted to corrosion. Its first officers were F. N. Speller, chairman; R. M. Burns, vice chairman; and G. H. Young, secretary-treasurer. The first directory, published in August, 1940, listed delegates of 23 national technical organizations and individuals having special knowledge in the corrosion field. The delegates met regularly to discuss mutual corrosion problems and issued their first report in November, 1942, entitled "Survey of Exposure Testing Facilities."

Some time after the founding of the American Coordinating Committee on Corrosion, a group of corrosion technologists in the Southwest formed the National Association of Corrosion Engineers. Many members of other national organizations interested in corrosion joined the new society. As NACE grew in strength, it became obvious to members of the American Coordinating Committee on Corrosion that this new organization was the instrument by which the purposes of the Committee could be fulfilled and eventually, at the invitation of NACE, become part of NACE and functioned under the name of the Inter Society Corrosion Committee, holding its annual meeting at the same time and place as the NACE annual convention. The first meeting of the revised organization was held October 28, 1948.

Among the advances in the field of corrosion technology that can be traced to the American Coordinating Committee on Corrosion are Gordon Research Corrosion Conferences, growth of National Association of Corrosion Engineers, publication of Corrosion Handbook, exchange of information with corrosion groups of other nations, more uniform corrosion terminology and many other advancements toward making corrosion control a recognized profession. All this can be attributed to the group of founders headed by F. N. Speller.

The 1963 Annual NACE Conference will be held at Convention Hall, Atlantic City, N. J.

ISCC Chairman Gives Survey of Committee Activities in 1960-61

Subcommittee on Relations With Other Countries

This subcommittee of ISCC, consisting of Paul Delahay, Frank L. LaQue, Frank N. Speller and Aaron Wachter with Hugh P. Godard as chairman, should be congratulated on their fine work and results. As evident in reports published in CORROSION, Mr. Godard and his committee are increasing the degree and scope of communications with many countries.

This committee undertook a special project to determine and list the corrosion journals published throughout the world. (This list was published on Page 38 of the October, 1960, issue of CORROSION.) This study also included a study of broader journals in which corrosion papers appeared. This committee maintains correspondence with correspondents in 17 nations with plans for broader coverage underway.

Subcommittee on Standardization of Definitions

The Technical Association of Pulp and Paper Industries (TAPPI) is developing a data sheet in which the present ISCC standardized corrosion terminology definitions will be included.

In 1960, ISCC conducted a survey on the need for publication of standardized definitions. All responses were positive. Thirty-seven suggestions for journal publication points and 18 suggestions on book and handbook publication points were received. These suggestions have been turned over to the Definitions Committee.

Membership of Inter Society Corrosion Committee

The Society of Rheology withdrew its membership in ISCC in 1960. Present ISCC membership includes 32 societies.

ISCC Annual Report

Notices for annual member society reports were mailed on November 2, 1960, with responses from most members received by end of the year.

In 1959, Kenneth G. Compton and his committee originated a simplified annual report form for the purpose of standardizing member reports. The proposed form would permit easier summaries and consolidation of reports. It would be accompanied by an appendix to provide details on corrosion activities, particularly investigations. The form was revised slightly by comments from all society delegates and was first used for the 1960 annual report.

In response to a survey undertaken by ISCC in 1960, two letters were received which presented the thought that the needs which led to formation of ISCC and particularly the annual report of ISCC have since been fulfilled by regular publications. As a result of this response, we have asked the ISCC delegates and other interested individuals to attend the ISCC meeting in Buffalo, N. Y., to discuss the question of continuance of the committee in whole or in part.

Robert R. Pierce
Chairman



H. J. Etchison, District Superintendent for the Northern Illinois Gas Company, and Koppers Serviceman A. C. Hueseman, check Bitumastic coating on pipeline project near Belvidere, Illinois.

"It's a real help to have a coatings serviceman on the job!"

That's the way H. J. Etchison, District Superintendent for Northern Illinois Gas Company, summed up Koppers Serviceman A. C. Hueseman's role on the company's new 22 inch gas line in Illinois between East Dubuque and Des Plaines.

"A serviceman brings expert assistance to the men on the job," Mr. Etchison said. "It saved us time and money having a specialist on the spot to tackle unexpected coating problems. We've found that servicemen have solved most of these problems on other jobs and they're able to anticipate possible trouble spots in advance."

Northern Illinois Gas Company's new line delivers gas from a supplier into its system serving suburban Chicago. It is

typical of installations where serviceman Hueseman has helped gas companies with the application of high quality Bitumastic® Enamels. And his travels have carried him across the nation so many times that, as he says, "almost anywhere is home."

A Koppers field service specialist can help you get the most for your corrosion-prevention investment. For more information on the proved performance of Bitumastic pipeline coatings, mail the coupon or write: Koppers Company, Inc., Tar Products Division, Pittsburgh 19, Pennsylvania. District Offices: Boston, Chicago, Los Angeles, Pittsburgh, New York, Woodward, Ala., Houston, Texas (Mavor-Kelly Company). In Canada: Koppers Products, Ltd., Toronto, Ont.



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Firm _____

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Overseas Correspondents

Corrosion Activities in Germany

Listed below is a summary of activities of German scientific and technical societies and their corrosion committees in the field of corrosion for 1960.

1. The Sewage Association (Abwassertechnische Vereinigung) issued instructions on rust removal, primers, metallic coatings and finish coatings.

2. The Corrosion Task Group of the Technical-Scientific Associations (Arbeitsgemeinschaft Korrosion der technisch-wissenschaftlichen Verbände) held a session on "Corrosion and Corrosion Protection on Shipboard and in the Harbour" in which Corrosion Committees 6, 11, 12 and 16 participated.

3. The Information Centre for Seaworthy Packaging (Beratungsstelle für seemässige Verpackung) held a discussion on "Packaging in the Electrical Industry."

4. The German Bunsen Society for Physical Chemistry (Deutsche Bunsengesellschaft für physikalische Chemie) dealt with, among other subjects at its 1960 annual meeting, the formation of phosphate coatings, solid state reactions of silver, absorption of tagged ions on metal surfaces and the electrochemical behavior of chromium, beryllium and amalgams.

5. The German Metallurgical Society (Deutsche Gesellschaft für Metallkunde) arranged a European symposium on cathodic protection.

6. The German Committee for Steel Construction (Deutsche Ausschuss für Stahlbau) dealt with cathodic protection of painted structures and the embrittlement in hot galvanized structures.

7. The German Specification Committee, Sub-Committee for Material Testing (Deutsche Normenausschuss, Fachnormenausschuss Materialprüfung) published specifications and draft specifications on atmospheric corrosion testing devices and on the testing of the impact resistance of enamel, the corrosive acid and chloride content of paper and water, the corrosion protective action of electrical insulating materials and wood preservatives, as well as corrosion protection by greases and steam turbine oils. It published a revision of a specification on corrosion attack.

8. The Germany Society of Gas and Water Specialists (Deutsche Verein von Gas- und Wasserfachmannern) published treatises on cathodic protection and guides on effect of chemical composition and electrical resistance on corrosion of steel. It arranged a course on stray currents and cathodic protection.

9. The Research Organization for Internal Combustion Engines (Forschungsvereinigung für Verbrennungskraftmaschinen) carried out cavitation corrosion investigations in the cooling cycle of internal combustion engines.

10. The German Chemical Society (Gesellschaft Deutscher Chemiker) spent, through the Federal Ministry of Economics, 364, 273 DM for corrosion research in various fields. Its committee "Paints and Pigments" worked on short-term weathering tests, air and water permeability and the film formation of paints and held six open-discussion evenings. The committee on "Water

Chemistry" worked on a specification of the resistance of asbestos cement to aggressive waters.

11. The Harbour Construction Society (Hafenbautechnische Gesellschaft) concerned itself with constructive methods of reducing the corrosion of harbor structures and with rust tests in the water of various large harbors.

12. The Society of Shipbuilders (Schiffbautechnische Gesellschaft) published information on mill scale removal from ship plate.

13. The Bituminous Coal Mining Society (Steinkohlenbergbauverein) carried out electro-magnetic and potential measurements on coatings to evaluate the protective effect of zinc coatings on supply wagons. These made possible a satisfactory estimate of the protection to be expected.

14. The German Electro-Technical Society (Verband Deutscher Elektrotechniker) published measuring methods for evaluating stray current corrosion and prepared a chart of cathodic protection installations in Germany.

15. The Society of German Engineers (Der Verein Deutscher Ingenieure) completed research work on the installation of chemical and electrochemical corrosion protective methods in heating.

16. The German Iron and Steel Association (Verein Deutscher Eisenhüttenleute) worked on instructions for the use of stainless steels for sheet and tubing in various applications and for surgical instruments. It carried out cooperative natural rusting tests with various steels in rural, industrial and marine atmospheres.

17. The Society of Large Boiler Owners (Vereinigung der Grosskesselbesitzer) investigated corrosion prevention on the flue gas side of high pressure steam boilers by synthetic, metallic, tar and ceramic coatings.

G. Schikorr

Chemische
Landesuntersuchungsanstalt
Stuttgart

February 6, 1961

New Committee to Make Young Author Awards

A separate Young Author Award Committee has been formed by the NACE Education Committee to make selection of that annual award given to the author of a technical paper published in CORROSION which is considered to be of superior quality and originality. The paper must be submitted for publication before the author's 30th birthday.

Selection of the young author for this award previously was handled by members of the Education Committee.

Norman Hackerman, chairman of the Chemistry Department at the University of Texas, Austin, Texas, has been appointed chairman of the Young Author Award Committee. His vice chairman is M. G. Fontana, chairman of the Department of Metallurgy at Ohio State University, Columbus, Ohio. R. B. Hoxeng of U. S. Steel Corporation's Applied Research Laboratory, Monroeville, Pa., has been appointed as a committee member.

LaQue Named Planning Committee Vice Chairman

Frank L. LaQue, vice president of International Nickel Co., Inc., New York, N.Y., has been appointed vice chairman of the NACE Policy and Planning Committee. Chairman is R. A. Brannon of Humble Pipe Line Co., Houston, Texas.



1961

Oct. 4-6—Western Region Conference, Benson Hotel, Portland, Oregon.

Oct. 9-11—North Central Region Conference, St. Louis, Chase Park Plaza Hotel.

Oct. 24-27—South Central Region Conference and Exhibition, Shamrock-Hilton Hotel, Houston.

Oct. 30-Nov. 2—Northeast Region Conference, New York City, Hotel Statler.

Nov. 27-Dec. 1—Southeast Region Conference and Florida General Conference Short Course, Key Biscayne Hotel, Miami, Fla.

Nov. 29-30—NACE Board of Directors Meeting, Key Biscayne Hotel, Miami, Fla.

1962

March 18—NACE Board of Directors Meeting, Muehlbach Hotel, Kansas City, Mo.

March 19-23—18th Annual Conference and 1962 Corrosion Show, Kansas City, Missouri, Municipal Auditorium.

March 23—NACE Board of Directors Meeting, Muehlbach Hotel, Kansas City, Mo.

October 1-4—Northeast Region Conference, Hotel Sheraton Ten Eyck, Albany, N. Y.

October 9-11—North Central Region Conference.

October 11-12—Southeast Region Conference, Birmingham, Ala.

October 16-19—South Central Region Conference and Exhibition, Granada Hotel, San Antonio.

1963

March 18-22—19th Annual Conference and 1963 Corrosion Show, Convention Hall, Atlantic City, N. J.

October 14-17—South Central Region Conference, Oklahoma City, Okla.

SHORT COURSES

1961

June 5-9—Corrosion Short Course, co-sponsored by NACE Greater St. Louis Section and Washington University, to be held at Washington University, St. Louis.

June 6-8—6th Annual Appalachian Underground Corrosion Short Course, University of West Virginia, Morgantown.

June 7-8—Teche Section Short Course, University of Southwestern Louisiana, Lafayette, La.

June 20-21—Greater Boston Section Corrosion Short Course, Wentworth Institute, Boston, Mass.

Sept. 27-29—8th Annual Central Oklahoma and University of Oklahoma Corrosion Control Short Course, Norman.

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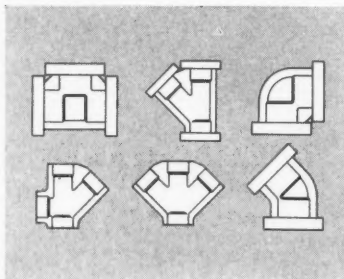
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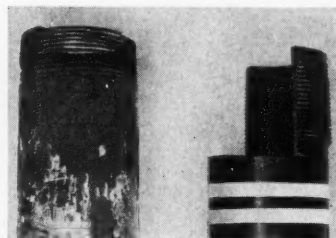


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CORROSION ABSTRACTS

INDEX TO CORROSION ABSTRACTS

Vol. 17 May, 1961 No. 5

6. MATERIALS OF CONSTRUCTION

6.3 Non-Ferrous Metals and Alloys—Heavy	73
6.4 Non-Ferrous Metals and Alloys—Light	74
7. EQUIPMENT	
7.6 Unit Process Equipment	74
7.7 Electrical, Telephone and Radio	74
8. INDUSTRIES	
8.4 Group 4	76
8.8 Group 8	76

6. MATERIALS OF CONSTRUCTION

6.3 Non-Ferrous Metals and Alloys—Heavy

6.4.2, 8.4.5, 3.5.4

Aluminium in Reactor Construction. P. Eversheim. *Atomwirtschaft*, 4, 155-159 (1959). Translation IGIS-70(RD/R) by R. Pentland on Deposit in the Depository Libraries.

Properties of aluminum and its alloys are reviewed with emphasis on those which meet the requirements for use in reactor construction. Corrosion characteristics are discussed and problems encountered in fuel element canning are examined. Radiation effects of neutrons are tabulated for various alloying materials.—NSA. 20208

6.3.6, 3.5.8, 5.8.1

Investigation of the Influence of Certain Inhibitors on the Corrosion Cracking of Metals. (In Russian.) S. A. Balezin, V. V. Romanov and N. I. Podobaev. *Proc. Acad. Sci. USSR, Chem. Tech. Sec. (Doklady Akad. Nauk SSR)*, 123, No. 5, 902-905 (1958). English Translation of Journal Available from Consultants Bureau, Inc., 227 W. 17th St., New York 11, N. Y.

Specimens of 70:30 brass sheet were stressed at 30 kg/mm² and exposed to the vapor from 25% ammonium hydroxide. Cracking could be entirely prevented by use of certain inhibited lubricants which are named.—MA. 18702

6.3.10, 3.5.9, 2.3.7, 3.7.4

Study on Ni-Cr Binary Alloys. Pt. I. On High-Temperature Strength. (In Japanese.) K. Suenaga and M. Okamoto. Paper before Japan Inst. Met., Apr. 1958. *J. Jap. Inst. Met.*, 22, No. 12, 648-651 (1958) Dec.

Experiment to investigate the high-temperature strength of nickel-chromium binary alloys containing 20-40% chromium in homogenized state, either as cast or rolled by 30% in reduction at 750 C, by means of high-temperature hardness and bend-creep tests. Rolled and homogenized specimens were harder in high-temperature and stronger in bend-creep test than the specimens

homogenized without rolling. The bend-creep strength of 35% chromium-nickel alloy at 700 C was maximum with homogenized specimens as cast, and in 25% chromium-nickel alloy the maximum value was obtained from rolled and homogenized specimens. By heating the specimens containing 30-40% chromium at 700 C for 100 hrs., a troostic structure was found at the grain boundaries spreading over the grains. This phenomenon was conspicuous in rolled and homogenized 40% chromium-nickel alloy. One cause for the weakness in bend-creep test of this alloy might be due to the troostic structure in the finer grains. A 20% chromium-nickel alloy showed a Widmanstatten structure with sub-grains after heating at 700 C for 100 hrs. This phenomenon might be related to so-called anomaly of γ solid solution at low temperature.—INCO. 17842

6.3.15, 4.3.2, 3.2.2, 3.5.8

Corrosion of Titanium in the System: HNO₃-HCl-H₂O. O. R. Klemens. Phillips Petroleum Co., Atomic Energy Div. U. S. Atomic Energy Commission Pubn., IDO-14479, October 2, 1959 (Declassified Feb. 3, 1960), 14 pp. Available from Office of Technical Services, Washington, D. C.

Corrosion behavior of 75A titanium in water-diluted and undiluted mixtures of reagent-strength nitric and hydrochloric acids has been investigated. These tests were at boiling temperatures in the immersed and vapor phases. The possibilities of hydrogen embrittlement and stress corrosion under test conditions were also investigated. Titanium weld studies were included. These tests were duplicated with Nichrome V present in the solution. (auth)—NSA. 20089

6.3.10, 4.3.2, 3.4.6, 3.8.4

Kinetics of Nickel Corrosion in Sulfuric Acid. C. H. Pitt and M. E. Wadsworth. University of Utah. *Trans. Met. Soc., Am. Inst. Mining and Metallurgical Engrs.*, 218, No. 3, 395-401 (1960) June.

Investigation of nickel corrosion in H₂SO₄ solutions at elevated temperatures and O₂ over-pressures. Corrosion follows linear rate with time. Ni does not corrode appreciably in absence of O₂ in concentration range studied (0.02-0.1 molar). Corrosion rate is zero order with respect to agitation above given minimum, which indicates that bulk diffusion is not controlling factor. Experimental results and theory developed indicate single site absorption of undissociated acid molecule which in turn reacts with O₂ to promote Ni corrosion: rate controlling step being diffusion of O₂ through limiting boundary film on Ni surface. Increase in corrosion rate is directly proportional to O₂ partial pressure above solution up to 600 psi partial O₂ pressure (extent of determination). Calculation of number of possible sites using absolute reaction rate theory indicates that very small percentage of Ni surface is reactive. Reaction steps are presented. Tables, graphs, 18 references.—INCO. 20097

6.3.20, 3.7.2, 4.6.1, 3.2.2

Effect of Additions to Zircaloy on

Hydrogen Pickup During Aqueous Corrosion. Warren E. Berry, Earl L. White and Frederick W. Fink. Battelle Memorial Inst. U. S. Atomic Energy Commission Pubn., MI-1402, December 29, 1959, 32 pp. Available from Office of Technical Services, U. S. Department of Commerce, Washington, D. C.

An investigation was conducted into the possibility of alloy additions to Zircaloy-2 to diminish hydrogen absorption during aqueous corrosion. The nickel in Zircaloy-2 is believed to be the major constituent responsible for the relatively high hydrogen absorption. Additions of up to 0.5 wt.% antimony, arsenic, bismuth, or tellurium were selected on the basis of their known ability to poison the catalytic effects of nickel in hydrogenation reactions of other systems. Results of tests conducted for a total of 224 days in 600 and 680 F water and 750 F steam revealed no decrease in hydrogen absorption in modified Zircaloy-2 containing the afore-mentioned alloy additions. Hydrogen absorption increased when these alloying elements were present in the range of 0.1 to 0.2 wt.%. Corrosion resistance also decreased with alloy additions in these ranges. A 2-atm. partial pressure of hydrogen in the steam or above the water did not affect hydrogen absorption in the alloys appreciably. The hydrogen partial pressure did not affect time to transition in corrosion rates, but did appear to produce higher wt. gains than degassed water. (auth)—NSA. 20281

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6.3.14, 6.3.8, 3.5.9, 3.7.2

Oxidation Rate of Molten Bearing Alloys. (In Polish.) S. Balicki and J. Ruzs. *Prace Inst. Hutniczych*, 10, No. 1, 29-39 (1958).

Oxidation rates of: (1) high-tin alloy containing antimony 11.2 and copper 5.07%; (2) tin-lead alloy containing antimony 14.5, tin 9.7, copper 1.03, nickel 0.7, cadmium 1.92, arsenic 1.6%; (3) lead alloy containing sodium 1.12, calcium 1%, were studied by measuring the gain in weight on 1-2 hr. oxidation at 500-700 C. Oxidation of (1) proceeds at a constant rate of 1-2 mg/cm²/hr and is governed by the compactness of oxide film (mostly SnO₂). The oxidation rate of (2) increases rapidly at temperatures > 550 C, mainly owing to the high rate of oxidation of cadmium and segregation of nickel in the surface. Alloys containing arsenic oxidize at a rate of 10 mg/cm²/hr, increasing tenfold at approximately 650 C. The oxidation rate of (3) is approximately 40 mg/cm²/hr, but further studies are necessary to determine sodium and calcium losses. 20 references.—MA. 18693

6.4 Non-Ferrous Metals and Alloys—Light

6.4.4

Magnesium in Aeronautics and Nuclear Engineering. E. F. Emley. *Light Metals*, 22, 242-246, 258-259, 283-286 (1959) Oct., Nov. Dec.

Paper was the substance of a lecture delivered in Stockholm, March 25, 1958, with minor additions covering recent alloys. Designations, compositions and tensile properties of magnesium casting and wrought alloys are tabulated, and high temperature proof stress (casting and sheet alloys) and typical and short-time creep (casting alloys) and time to rupture (sheet alloys) data are plotted. For short term use ≤ 280 C, MSR, and above MTZ (HK31-T6) are outstanding for castings; ZTY (Zn 0.5, Zr 0.7, Th 0.75, Mg balance %) sheet has attractive tensile and short-time creep properties and long-time creep resistance in the as-rolled state; the alloy appears useful for extrusions and forgings. Considering high temperature properties for certain missile applications there is an interest in very high rates of heating and loadings; it seems likely that alloys with high proof stress at temperature will be the most suitable. Cast and wrought forms, forming and welding are summarized. Plots show the strength/weight advantage of cast magnesium and the favorable resistance of sheet to buckling pressure. Tensile properties of bars cut from undercarriage castings in Elektron Z5Z are summarized. Cast Mg is particularly suitable for acid etching to form thinwalls. Corrosion and protective treatments are summarized. A fluoride anodizing process by Magnesium Elektron Ltd. cleans sand castings and leaves a surface resistant to corrosion. Cast and wrought applications in the aircraft industry, uses for guided missiles, including electronics, also nuclear applications, are described, with illustration and makers. The advantages of Mg are summarized.—LMB. 20209

6.4.2, 3.4.9

Effect of Relative Humidity on the Rate of Dissolution of Aluminium in Iodine-Methanol Solution. D. F. MacLennan. *J. Applied Chem.*, 9, Pt. 10, 519-520 (1959) Oct.

In the isolation of surface films from aluminum alloys by dissolving the metal

in iodine-methanol solution, the rate at which the aluminum is dissolved depends upon the relative humidity of the atmosphere in contact with the solution. Controlled-humidity experiments showed that at 30 C, the most favorable relative humidity is about 38%.—BTR. 19948

6.4.2, 3.5.9, 3.2.2.

New Aluminum Alloy Not Prone to Brittle Fracture. R. D. Olleman and G. C. Wolfer. *Kaiser Aluminum and Chemical Corp. Welding Engr.*, 44, No. 11, 42-45 (1959) Nov.

One of newest and strongest of Al-Mg-Mn alloys, 5083, offers extremely desirable combination of properties for cryogenic equipment; excellent weldability and weld ductility, good corrosion and stress corrosion resistance. Four tests were used to evaluate resistance of 5083 plate and its welds to brittle fractures: tensile tests, unnotched and notched tensile impact tests and Charpy impact tests. In each case, temperatures ranged from 75 to -320 F. Results are presented in graphs. No ductile-brittle transition was found in 5083-H113 Al alloy plate, or in 5183 weld deposits under any of the test conditions at temperatures down to -320 F.—INCO. 19859

6.4.2, 4.6.1, 3.2.3, 3.2.2

High-Temperature Corrosion by Water of Annealed Monocrystals of A9 Aluminium. (In French.) P. Lelong and J. Hérenquel. Paper presented at the Fall Meeting of the French Metallurgical Society, Paris (France), October, 1958. *Mém. Sci. Rev. Mét.*, 56, 663-674 (1959) Dec.

In monocrystalline, as well as in polycrystalline samples, the attack may develop in two distinct forms: (1) evolution of a uniform film; (2) random attack characterized by pitting. In monocrystals, the localized attack tends to follow the pattern of banding and it is at a later stage only that it becomes a general effect. If the samples are sufficiently thin, the stresses arising at the metal-oxide interface, as a result of dimensional changes in the growing oxide film, will cause flow phenomena, similar to those observed in polycrystalline samples. In the case of thicker samples this flow effect is limited to the metal-oxide interface resulting in an undulated surface of the same. 15 references.—ALL. 19831

7. EQUIPMENT

7.6 Unit Process Equipment

7.6.4, 5.8.4, 8.2.2

Corrosion in Power Station Feed Systems. A Trial of Cyclohexylamine and Morpholine and Their Evaluation as Corrosion Inhibitors. B. Tuck and E. M. Osborn. *Chemistry and Industry*, No. 13, 326-331 (1960) March 26.

Description of work carried out on a boiler feed system before and during dosing with volatile amines cyclohexylamine and morpholine. Conditions in each case were studied for approximately 3 months, aim being to assess value of feed line dosing with volatile amines and also to compare effects of two compounds with respect to breakdown to ammonia, distribution and metal pick-up. Materials of construction included 70/30 brass condenser tubes and pre-heater tubes, Cu-Ni ejectors, and 90/10 Cu-Ni high-pressure heater tubes. Sampling arrangements are described; economizer inlet samples were taken after flowing through approximately 50

ft. of iron pipe, reducing orifice and cooler. Analytical methods employed are described, and mathematical analyses of results (Cu, Fe, ammonia, and dissolved O₂ determinations, plus data on conductivity pH, and CO₂) are tabulated. Morpholine was slightly more effective in controlling metal pick-up. Despite advantages gained by use of volatile amine treatment, meticulous control of dissolved O₂ is required in order to achieve maximum reduction of Cu and Fe in boiler feed water. 13 references.—INCO. 19955

7.6.4, 4.6.2, 5.8.2

Investigation of Corrosion Mechanisms in Idle Boilers and Condensate Systems. F. E. Clarke and A. J. Ristaino. *Naval Engineering Experiment Station. Research and Development Rept.* 610314 A, April 28, 1958, 54 pp. Order PB 145357 from Library of Congress, Photoduplication Service, Publications Board Project, Washington 25, D. C.

Among factors that contribute to corrosion in idle boilers are partially filled tubes and conventional boiler water treatment chemicals in presently prescribed concentrations which tend to localize attack rather than to prevent it completely in partially filled ferrous containers. Sodium nitrite appears to be the most promising chemical inhibitor of corrosion in idle boilers.—GRR. 20300

7.6.4, 4.3.3, 6.2.3, 6.2.5

Causes of Deterioration in Boiling Tubes Used in the Production of Alumina. (In Russian.) Ya. D. Averbuch and K. G. Potaskuev. *Tsvetnye Metally*, 1959, 58-64, October.

Importance of material selection in the production of boiling tubes. Comparative corrosion resistance of various alloy and carbon steels when exposed to alkaline aluminate solution from 100-150 C. Best resistance is found in 10KhSND, 15KhSND and 16 M steels. 7 references.—RML. 20142

7.7 Electrical, Telephone and Radio

7.7.

Alumoweld: A New Bimetallic Wire for Electrical and Strength Applications. F. E. Leib. *Wire and Wire Products*, 34, No. 3, 327-329 (1959).

Al-covered steel wire is made by a continuous application of atomized Al powder on to steel rod, and by refining both the weld and the cladding with heat and pressure. Such rods are cold-drawn into wire for overhead-line appn. A 25% by area construction has at LF an electrical conductivity 33% that of EC Al wire. Owing to skin effect, at HF this approaches 100%. Using high-strength steel, a UTS approximately that of Copperweld or ACSR core wire is attained. Resistance to corrosion is as good as that of EC Al.—MA. 19785

7.7, 6.2.2, 6.2.3, 6.4.2, 6.3.6

Electrical Installations in Corrosive Environments. R. P. Northup. *Crouse-Hinds Co. Corrosion Technology*, 6, No. 11, 344-346 (1959) Nov.

Reviews corrosion resistance of most commonly used metals in electrical installations in chemical plants and other corrosive environments. Cast iron, steel, Al, brass, bronze and Cu are covered. Advantages and disadvantages of these metals, together with pertinent design



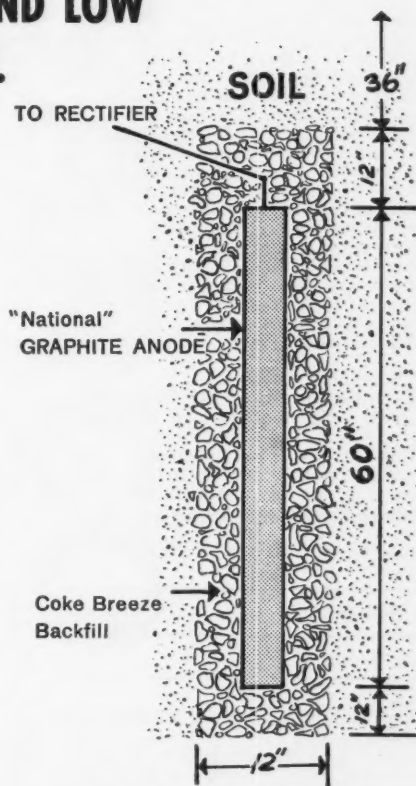
GRAPHITE ANODES OFFER LONG LIFE AND LOW COSTS PROTECTING 11,000,000 SQ. FT. OF UNDERGROUND STEEL IN SPAIN

"National" graphite anodes for cathodic protection are used around the world. In 1958 four-hundred-sixty 3"x60" "National" graphite anodes* were installed to protect the 620 mile Spanish J.U.S.M.G. pipeline from Rota to Zaragoza. The 12", 10", 8" and 6" diameter coated steel pipeline with attendant service pipelines of varying diameters, plus twenty-six tank bottoms total approximately 11,000,000 square feet of steel under cathodic protection.

Because of the wide variations in soil resistivity along the pipeline, each anode and rectifier installation had to be individually engineered. Twenty-six rectifiers with outputs ranging from 20 volts DC to 200 volts DC, from 40 amps to 100 amps were used.

The graphite anodes were placed on 20 foot centers in 12" diameter x 120" deep holes surrounded by well tamped coke breeze backfill. The number of anodes in each bed varied, depending upon the current discharged and the soil resistivity. The system is designed to operate for more than ten years.

*Wayne Broyles Engineering Company supplied the equipment and installed the cathodic protection system.



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factors, are discussed. Cu parts are best protected by Ni plating. Plastic coatings are considered.—INCO. 19867

7.7, 6.4.2, 8.4.3, 7.4.1

Aluminum Conduit and Fittings Arch-Foe of Corrosion. H. M. Tomlinson, Jr. Celanese Corp. of Am. Chemical Processing, 23, No. 3, 96-98 (1960) March.

After 2½ years of service, aluminum power and lighting conduit and Cu-Free Al Conduit fittings on cooling towers of petrochemical plant have shown no indication of corrosion in atmosphere of Gulf Coast climate and exposure to plant fumes and cooling tower vapors.—INCO. 19966

7.7, 4.2.5, 3.6.6, 5.2.1

How CATC Fights Marine Corrosion in an Offshore Mobile Tank Battery. R. M. Robinson. Continental Oil Co. Oil & Gas J., 56, No. 41, 117-119 (1958) October 13.

CATC's Tank Battery No. 2 in West Delta Block 84 field was given the full treatment to prevent corrosion. Review of battery revealed that it is exposed to both external and internal corrosion. External corrosion results from the marine environment in which the tank battery is located. Corrosion in submerged zone is attributed to galvanic corrosion around welds or small differences in the metal, solution of steel resulting from stray currents and reaction between the steel and chemicals in the sea water. Corrosion in splash zone results from galvanic action between small differences in the metal, and because of potential differences at different heights caused by varying oxygen concentrations. Corrosion in the atmosphere zone results from reaction between oxygen in the air and the steel in the presence of salt-spray or water condensed from the humid atmosphere. Cathodic protection alone is most suitable for the submerged zone and barrier coatings were used for the other two zones. Corrosion rate in the splash zone indicated that the application of expensive, long lasting protection is justified. Consequently, Monel sheathing was selected for this area. A 5 coat modified vinyl-chlorinate rubber system was used as the barrier coating of the atmospheric zone. Chemical inhibitors were used to guard against internal corrosion. Photos.—INCO. 18057

7.7, 5.2.1, 6.3.8, 6.4.2

Corrosion in Electrical Engineering. Michael Graham. Corrosion Prevention and Control, 5, No. 10, 49-50 (1958).

Use of lead and aluminum cable sheaths, cathodic protection of underground cables, atmospheric corrosion at aluminum and copper conductors, corrosion of copper wires and design of electrical contacts are briefly discussed.—MA. 18128

8. INDUSTRIES

8.4 Group 4

8.4.3, 5.2.1, 5.4.5, 4.6.4

Corrosion in Salt Water Cooling Systems. Pts. I & II. E. D. Dolan. Paper before 5th World Petroleum Congress. Corrosion Engr. (Corrosion Prevention & Control), 1, Nos. 3, 5; 4, 2-10 (1959) June, August.

Describes experimental work at B. P. Refinery Ltd. In channel ends and floating head ends of condensers, Mg anodes (directly connected, with resist control and with aluminum sheathing) were suc-

cessful in preventing corrosion. Zn anodes gave adequate protection when combined with coatings and stainless steel facing of flange mating with tube plate. Protection method, based on epoxy mastic coating and full-face Fe anodes, is suggested. Reliable tube plate coating is required to increase life of sacrificial anodes. Section of 60 in. diameter steel cooling water main was protected internally by impressed current; optimum anode spacing is 4 diameters. At water velocities up to 2½ fps, current density of 5 mA/sq. ft. gave protection. Promising results were obtained with coating of epoxy mastic, aluminum-bitumen paint, Zn rich primer plus coal tar top coats and synthetic rubber-cement mastic. Tables, graphs, diagrams, 10 references.—INCO 20258

8.4.5, 4.6.4, 3.5.4

Activation Analysis of Closed Circuit Shield Cooling Water. W. A. Rhoades. Atomics International Div., North American Aviation, Inc., NAA-SR-Memo-4214, October 8, 1959, 14 pp. Available from Office of Technical Services, U. S. Department of Commerce, Washington, D.C.

Activity due to corrosion contamination and N¹⁶ in the shield coolant water for the HNPF was examined. Studies were made to determine if a proposed pH and contamination control system will significantly reduce the radiation levels from the cooling system. The hazard resulting from collection of the corrosion products in the filters and demineralizers was also studied.—NSA. 19890

8.4.5, 3.8.4, 6.2.3

Chemical Investigations in High Temperature Water Loops. J. K. Linacre and H. Morley. United Kingdom Atomic Energy Authority. Research Group. Atomic Energy Research Establishment, Harwell, Berks, England. AERE-C/R-2853, Nov., 1959, 130 pp. Available from British Information Service, 45 Rockefeller Plaza, New York 20, New York.

Corrosion rate of a mild steel water loop was investigated, after thorough cleaning by sulfuric acid pickling, by following the rate of change of hydrogen concentration in solution. Suitable corrections for loss of hydrogen by leakage and by diffusion through the loop steel were applied. The loop water was controlled at a pH of 10 to 11 by addition of KOH and by ion exchange and kept at an operating temperature of 260 C. The corrosion rate was found to fall rapidly, from an initial value of $>0.4 \text{ mg dm}^{-2} \text{ hr}^{-1}$ to $0.04 \text{ mg dm}^{-2} \text{ hr}^{-1}$ after 300 hr. The rate of release of corrosion products, estimated by collection in a purification unit, was of the order of $10^{-3} \text{ mg dm}^{-2} \text{ hr}^{-1}$. If the steel was unclean and initially covered with a layer of low temperature oxide, the initial corrosion rate was lower than for the clean steel, but the rate of release of corrosion products was greater by a factor of 10, even after 300 hr. exposure. On admission of oxygen to the corroded steel system, some oxidation of the Fe_2O_3 corrosion film to Fe_3O_4 occurred, but the major action appeared to be further attack on the steel to form Fe_3O_4 . On first adding oxygen and at high oxygen concentrations, the rate of reaction was proportional to the oxygen concentration and inversely proportional to the film thickness. The film thickness increased as reaction proceeded. The rate constants for mild steel were determined to be: $k = 275 \text{ cm}^3 \text{ dm}^{-2} \text{ hr}^{-1}$

and $p = 80 \text{ (cm}^3 \text{ dm}^{-2})^2 \text{ hr}^{-1}$, and for stainless steel, $p = 3.2 \text{ (cm}^3 \text{ dm}^{-2})^2 \text{ hr}^{-1}$. In the case of stainless steel, chromate was formed in solution at a rate proportional to the hydroxyl ion concentration. A rate constant of 0.04 hr^{-1} was determined. The transfer of permanent gases from solution in the loop water to the vapor phase of the steam pressurizer was studied in the mild steel loop, relative to direct pressurization, degassing, and gas absorption connections of loop and pressurizer. Results were analyzed in terms of a mechanism involving stripping of gas from the pressurizer liquid phase by steam bubbles rising from the immersed heater. (auth)—NSA. 19885

8.8 Group 8

8.8.1, 4.3.2, 2.3.8

Swedish Heavy Water Process. (In English.) B. J. Eriksson. Chem. & Process Eng., 41, 5-7 (1960) Jan.

A process for producing heavy water by the dual-temperature isotope exchange between hydrogen sulfide and water is described. Technical and safety problems involved in the process are discussed. The corrosive effects of hydrogen sulfide on various components of the pilot plant are described.—NSA. 20196

8.8.3

Plating Parts by Peening Them. Herbert L. Kee. Product Engineering, 31, 70-72 (1960) March 14.

Parts are rotated in a barrel with powdered coating material, steel pellets and grit and a chemical promoter. Corrosion tests are conducted on Zn-coated bolts and results are compared with those obtained from electroplated parts.—RML. 19881

8.8.5, 5.9.4

Impregnating (Aluminum) Castings Before Anodizing and Coloring. (In French.) Henry Garnier. Rev. Aluminium, No. 263, 349-350 (1959).

Garnier describes two methods used for preventing access of anodizing fluid into the pores of castings which cause staining after dyeing: (a) the castings, after anodizing, are treated in a neutralizing bath of ammonium oxalate; (b) they are impregnated before anodizing with a solution of bakelite under vacuum followed by pressure in an autoclave.—MA. 19154

8.8.5, 6.2.5

Investment Casting in the US and UK—Part II. Development of Corrosion-Resisting Investment Castings with High Mechanical Properties and Good Weldability. R. Taylor. Paper before European Investment Casters' Congress, Paris, 1958. Foundry Trade J., 106, No. 2217, 414-417 (1959) April 9.

As scope of lost-wax casting process broadened, need for an alloy to satisfy following demands became evident: heat-treatable to give high mechanical properties, high corrosion resistance, good weldability and available in form of investment castings of at least a reasonable standard. Article describes development of Firth Vickers alloy FV.520 with composition: 0.06 carbon, 0.7 silicon, 0.7 manganese, 5.5 nickel, 15.0 chromium, 1.5 copper, 2.0 molybdenum and 0.1-0.5 titanium or niobium. Tables and graphs present weld-test mechanical properties obtained after stress-relief; heat-treatment-induced precipitation effects; linear coefficients of thermal expansion; and mechanical properties.—INCO. 18561

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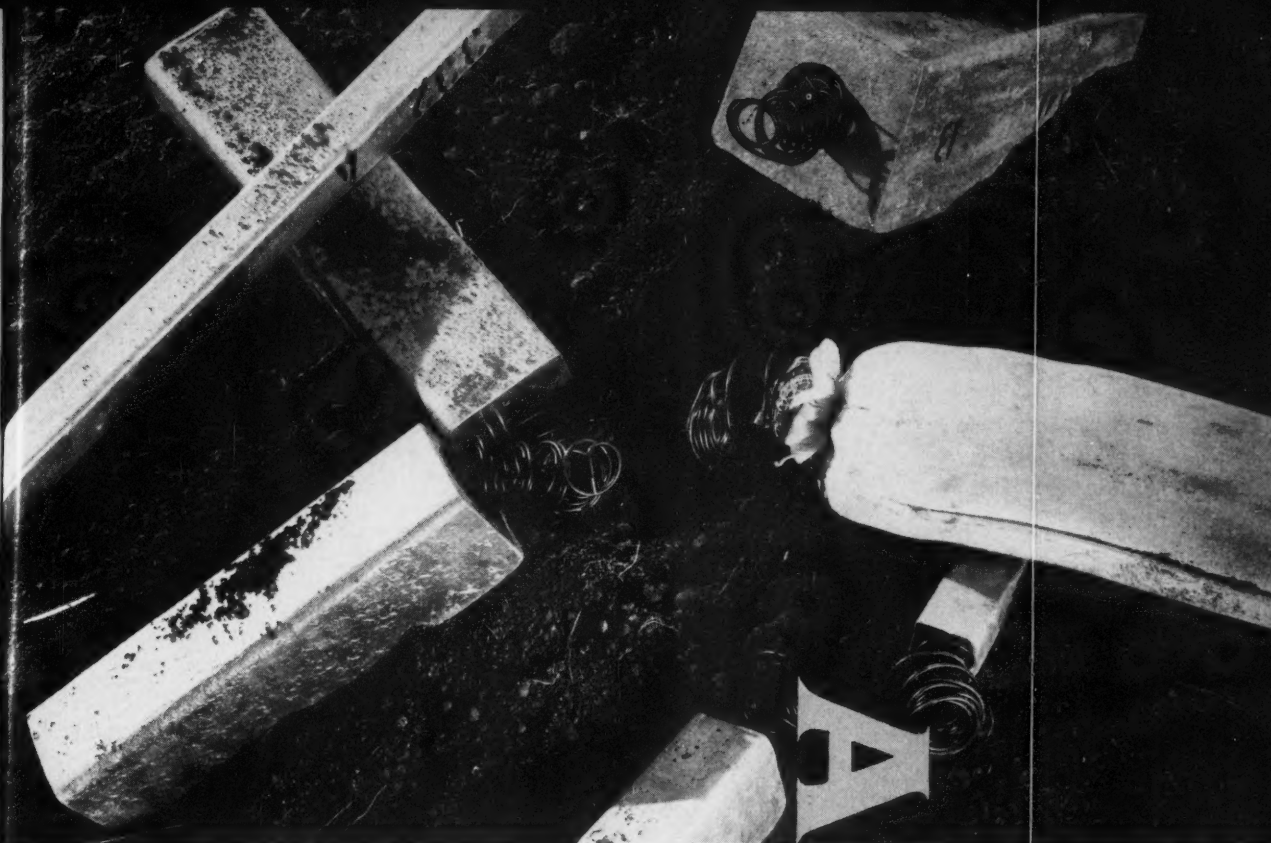
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Topic of the Month

High Temperature Sulfur Corrosion Of Intermediate Range Chromium Steels*

By R. E. HANNUM*

Introduction

CORROSION BY high temperature sulfur in thermal desulfurization units has been a problem ever since these units went into service about 20 years ago. The effects of high temperature sulfur corrosion are well known. Presently, several groups are studying the mechanisms of this type of attack.¹ Even though there is much published data on the subject there are still many unknown factors at work in specific refinery units.

In high temperature sulfur environments the chromium and chromium-nickel stainless steels or aluminum coatings generally are used to resist the corrosive forces. In one specific case the author found the higher range intermediate chrome steels (9 percent) to be economically useful.

Discussion

A furnace oil desulfurization unit was originally put in service in 1943 to desulfurize light, straight run naphtha from West Texas Permian crudes. It was then converted in 1950 to desulfurize furnace oil from West Texas Permian crudes. The general service conditions are as follows: average furnace outlet temperature—650 to 675 F; pressure—50 psig average; velocity of the material—75 ft/sec. At the outlet of the furnace and through the transfer line the material is 100 percent vapor. Five percent chromium, 1/2 per-

cent molybdenum material was considered sufficiently resistant to these service conditions in the furnace tubes and transfer lines. In fact, for a good many years this material gave very good service. However, the service factor for the unit was low—in the order of 33 percent.

Table 1 shows the sulfur and sulfur compound content of the furnace oil charge for several periods during the past ten years. Note that there has been little change in the sulfur or mercaptan contents. However, the H₂S content has increased considerably and this could be

Abstract

Laboratory tests were made to find a suitable replacement material for 5 percent chromium—1/2 percent molybdenum tubes used in a thermal desulfurization unit. The steel found most suitable for this use had a 9 percent chromium content. Maximum corrosion loss in wall thickness of this material was less than 0.030-inch, with a total expected life of at least five years. The sulfur content of various crudes commonly used in furnaces is reported.

8.4.3, 6.2.4

an important factor in the resulting increase in the yearly corrosion rate.

The furnace at Atlantic's Desulfurization Unit is a vertical Petrochem type containing 56 tubes with a 0.156-inch

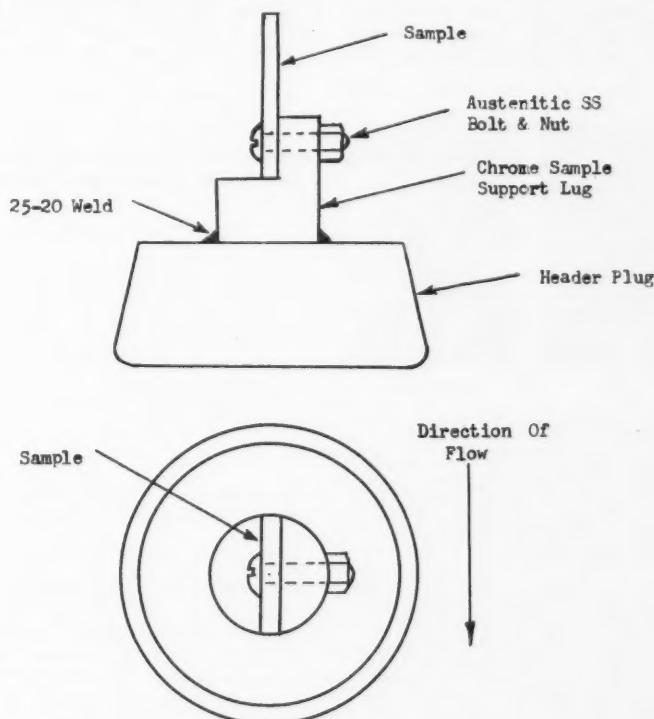


Figure 1—Sample installation.

* Submitted for publication December 7, 1960.

* The Atlantic Refining Co., Inc., Philadelphia, Pa.

TABLE 1—Sulfur and Sulfur Compounds in Furnace Oil Charge

Year	Type of Crude	Percent Sulfur	Mercaptans, MG/100cc.	H ₂ S, lb/1000 bbl.
1950	West Texas Permian	1.92	48.5	16.7
1952	West Texas Permian	1.30	56.2	44.6
1959	West Texas Permian	1.41	....	71.4
1960	West Texas Permian	1.39	51.2	130

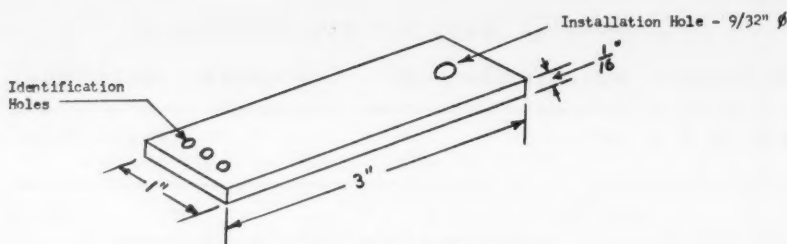


Figure 2—Typical test sample.

TABLE 2—Results of Examination

Sample No.	Alloy	Wt. Loss Percent	CORROSION RATES	
			MPY	Relative ¹
1a.....	2¼% Cr, 1% Mo	63.7	lost during run	1.00
1b.....	2¼% Cr, 1% Mo		93	
2a.....	7% Cr, ¼% Mo	19.5	28	.30
2b.....	7% Cr, ¼% Mo	29.3	42	.45
3a.....	12% Cr (Type 405 ss)	14.6	14	.15
3b.....	12% Cr (Type 405 ss)	16.8	16	.17
4a.....	Type 316 ss	4.5	8	.09
4b.....	Type 316 ss	4.6	7	.08

¹ Based on 2¼ percent Cr and MPY corrosion rates.

corrosion allowance. These are arranged in four separate coils of 14 tubes each. Tube length is about 35 feet.

During the years between 1945 and 1954, corrosion rates were moderate and the 5 percent chrome, ½ percent molybdenum tubes in use gave about six years of service on the average. Between the years 1954 and 1958 the service life dropped to about 21 months on the average.

A number of factors acted to increase the corrosion rate during this period. Perhaps the most important factor was the increase in the service factor for the unit. This increased from 33 percent during 1954 to over 80 percent during 1957.

As noted previously the H₂S content of the charge also increased during this time.

In 1957 a test sample program was initiated to find a suitable replacement material for the 5 percent chromium, ½ percent molybdenum tubes then being used. Samples were installed in headers at the bottom of eight tubes. The samples were attached to chromium steel lugs that were welded to the header plugs (see Figure 1.). Four materials were selected for the test; these were: 2¼ percent chromium, 1 percent molybdenum; 7 percent chromium, ½ percent molybdenum; 12 percent chromium (Type 405 stainless steel); and Type 316 stainless

steel. The samples were identified by small holes drilled at one end (see Figure 2.). The samples were installed in the furnace May 9, 1957. At the same time, eight 9 percent chromium tubes were also put in the furnace.

All samples were removed six months later for examination. The service factor during this run was about 82 percent. Results of the examination are shown in Table 2.

During this six month test period the 9 percent chromium tubes showed a maximum loss in wall thickness of 0.015-inch.

The seven remaining samples were reinstalled to continue the test. They were removed in August of 1958 after twelve months of actual service (15 months on intermittent running). Examination at this time confirmed the results found earlier (as shown in Table 2).

The 9 percent chromium tubes still showed a maximum loss of only 0.015-inch.

A curve of "relative corrosion rates" was plotted as a function of chromium content.² This curve was similar to that obtained by the U. S. Steel Company from field tests in cracking furnaces.³

On the basis of the results of these tests, 9 percent chromium material was chosen for use in furnace tubes and transfer lines. Maximum corrosion loss in wall thickness to date is less than 0.030-inch. It appears an average tube life of at least five years will be realized. Obviously this will result in a substantial saving in labor and dollar outlay with only a small increase in initial material cost.

References

1. API Subcommittee on Corrosion; and NACE Task Group T-5B-2 on Sulfide Corrosion.
2. J. J. Hur, The Atlantic Refining Company. R & D Corrosion Laboratory—Report 210-5. April, 1958.
3. *Ind. and Eng. Chem.*, 23, 738-741 (1931).

Any discussion of this article not published above
will appear in December, 1961 issue.

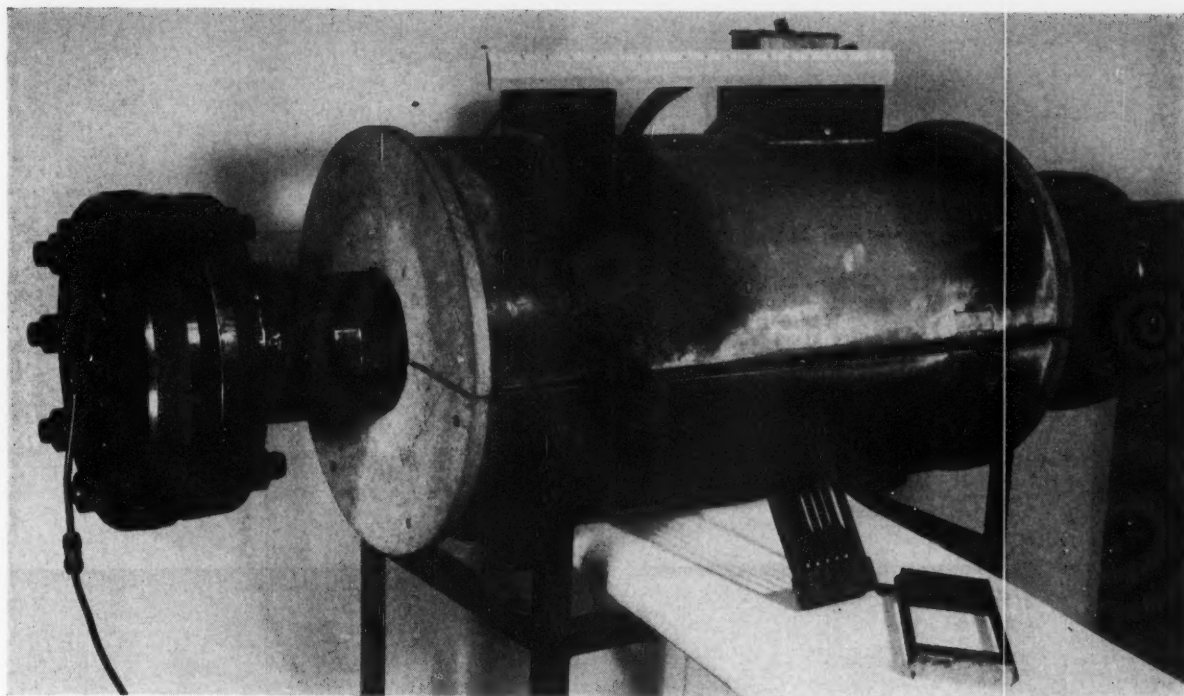


Figure 1—Furnace and gas corrosion frame.

Corrosion of Nickel-Based Alloys In High Temperature Nitrogen Environments*

By J. S. BRUNHOUSE and G. W. TITUS

Introduction

IN THE design and construction of a mobile, high-temperature, gas-cooled reactor for the U.S. Army, it was first necessary to select materials from which to fabricate the fuel elements. Selection criteria required a material capable of extended operation (5000-10,000 hours) at a hot-spot temperature of 1750F in atmospheres either of air or of 99.5 vol percent N_2 + 0.5 vol percent O_2 , under a maximum stress load of 1000 psi. The 99.5 vol percent N_2 atmosphere had been selected as a coolant for use with austenitic stainless steel claddings at an earlier point in the program.

Test Materials

After comparing some thirty alloys, six nickel-based alloys were selected for initial screening. These were: Inconel, Inconel X, Inconel 702, Hastelloy X, Hastelloy R-235, and Inor 8. Table 1 shows typical compositions. To reduce post-shutdown radioactivity in the system and to keep the nuclear poison in the fuel

Abstract

A nickel-based alloy was selected for cladding the fuel elements of a gas-cooled nuclear reactor. Criteria were good corrosion resistance to the coolant gas (300 psi 99.5 vol percent N_2 and 0.5 vol percent O_2) and reasonable mechanical strength at 1750F. Fuel element lifetimes of up to 10,000 hours were the ultimate aim. Materials tested include Hastelloy X, Inconel, Inconel X, Inconel 702, Hastelloy R-235 and Inor 8.

A representative cross-section of commercially available solid-solution and precipitation-hardened alloys were screened under the reactor conditions above. Hastelloy X showed the best properties and was therefore designated as the reference alloy toward which all design calculations and further evaluations would be directed. Inconel and Inconel 702 were somewhat less attractive but demonstrated sufficient promise to be considered as backup alloys.

8.4.5, 6.3.10, 4.3.5

elements to a minimum, alloys containing elements such as cobalt and boron were avoided.

As the table indicates, several examples of precipitation-strengthened and solid solution-strengthened alloys were selected on the basis of strengths and air corrosion resistance reported in the literature. As the form in which the material would be used was tubing, the availability and fabricability of tubing was investigated. However, to commence the testing pro-



Brunhouse

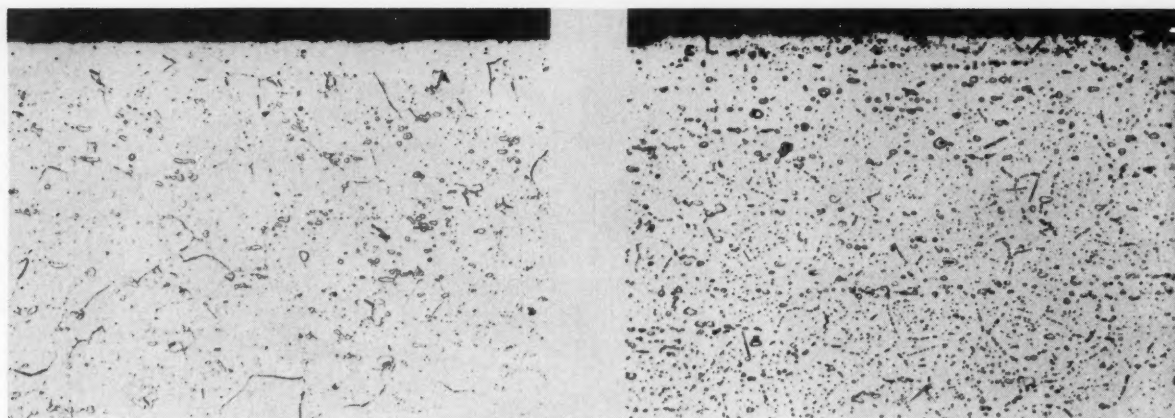


Titus

J. S. BRUNHOUSE received his BS degree in metallurgical engineering from the University of California in 1957. He was then employed by Union Carbide Metals Company on the research and development of reactive metals. Since 1959, he has been with Aerojet-General Nuclear Inc. in San Ramon, California as a metallurgist responsible for materials evaluation for the ML-1 reactor core. Mr. Brunhouse is a member of the American Society for Metals.

G. WALTER TITUS received his BS in chemical engineering from Oregon State College in 1950. He was employed by the Columbia Steel Company from 1953 to 1956. At Aerojet-General Nuclear Inc. since 1956 as a Senior Metallurgist and Task Engineer, he has directed evaluation of structural and fuel materials for elevated-temperature reactor applications. Mr. Titus is a member of the American Society for Metals and the American Ordnance Association.

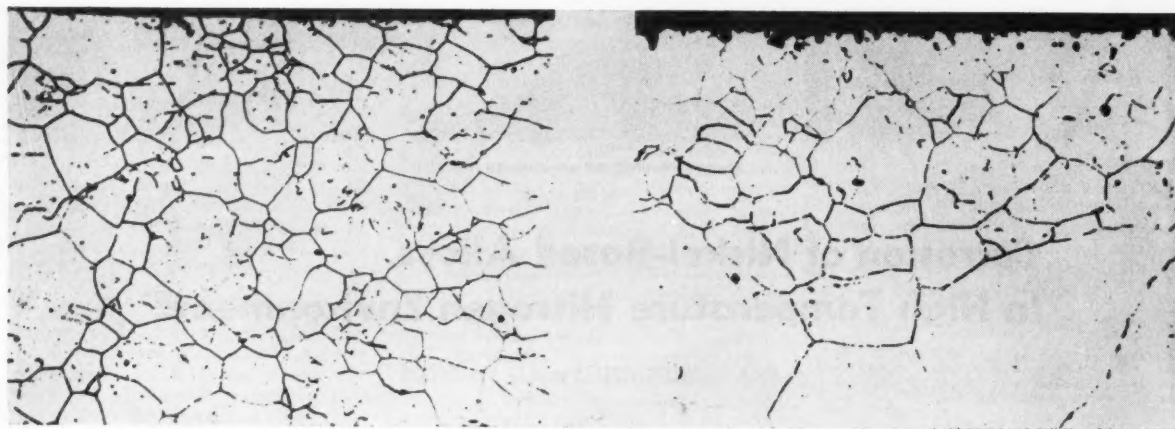
*Submitted for publication October 12, 1960. A paper presented at a meeting of the Western Region, National Association of Corrosion Engineers, San Francisco, Calif., October 6-7, 1960.



As Received

1000 Hr N₂ + 0.5 vol percent O₂ Gas, 1750 F.

Figure 2—Hastelloy X before and after exposure. Approximately 200X.



As Received

1000 Hr N₂ + 0.5 vol percent O₂ Gas, 1750 F.

Figure 3—Inconel before and after exposure. Approximately 200X.

TABLE 1—Chemical Compositions of Alloys for Screening

Alloy	CHEMICAL COMPOSITION, WT. PERCENT									
	Ni	Cr	Mo	Fe	C	Si	Mn	Ti	Al	Others
Inconel.....	70 min	17.0 14.0	.....	9.0 5.0	0.1 max	0.7 max	1.0 max	.....	.....	.....
Inconel X.....	70 min	17.0 14.0	.....	9.0 5.0	0.1 max	0.7 max	1.0 max	2.75 2.25	1.0 0.4	1.2 0.7 ^{Cb}
Inconel 702.....	70 min	17.0 14.0	.....	2.0 max	0.1 max	0.7 max	1.0 max	.25/1.0	3.0	.....
Hastelloy X.....	Bal	23.0 20.0	10.0 8.0	20.0 17.0	0.15 max	1.0 max	1.0 max	.....	.....	1.0 0.2 ^W
Hastelloy R-235.....	Bal	17.0 14.0	6.5 4.5	11.0 9.0	0.16 max	1.0 max	1.0 max	2.75 2.25	2.25 1.75	.....
Inor 8.....	Bal	8.0 6.0	18.0 15.0	5.0 max	0.08 0.04	0.5 max	0.8 max	.....	.....	.....

gram quickly, it was decided to use readily available 0.050-inch-thick sheet material.

As the literature values mentioned above were not on a common basis, short-time, creep-rupture screening tests were

performed. Comparative 50-hour stress-rupture valves at 1750F are shown in Table 2.

Table 3 tabulates for comparison elongations obtained in 1000-hour duration,

2000-psi stress, 1750F testing performed at a later point in the program.

Testing was carried out in 5-inch-OD, centrifugally cast Inconel retorts which were resistance heated in 5-inch-ID tube

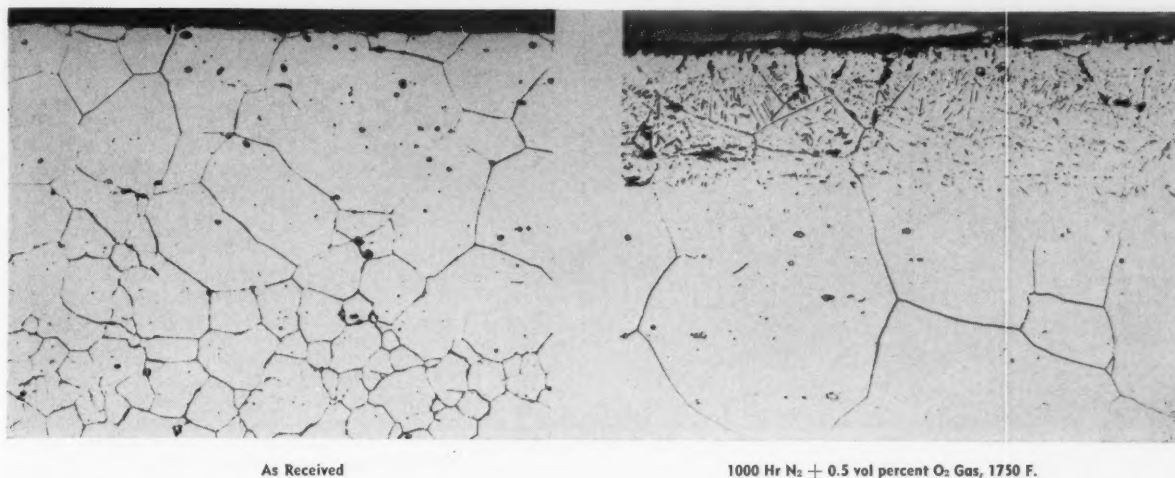


Figure 4—Inconel X before and after exposure. Approximately 200X.

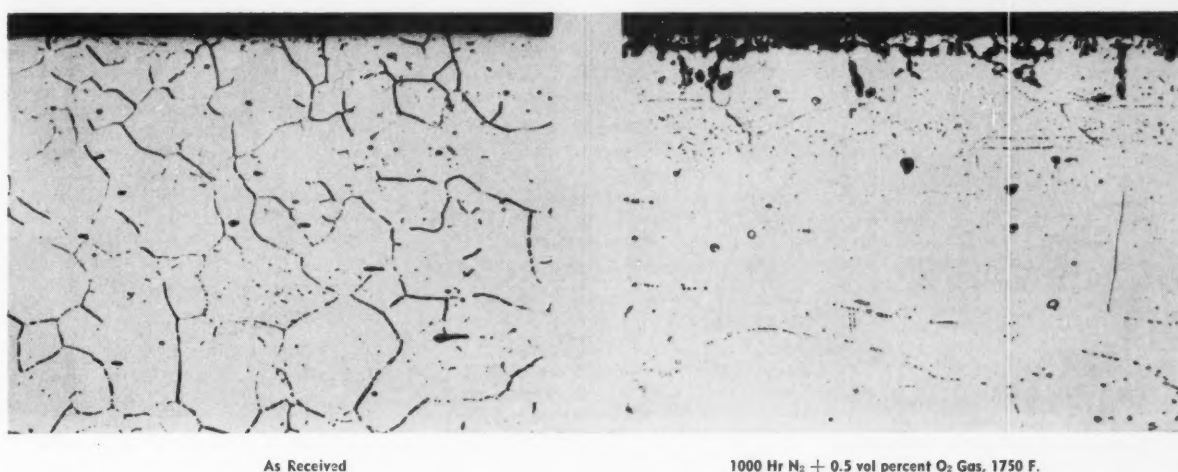


Figure 5—Inconel 702 before and after exposure. Approximately 200X.

furnaces. Each furnace was pressurized to the reactor operating pressure (200 psig) during operation with a slowly flowing gas (99.5 vol percent N_2 + 0.5 vol percent O_2) atmosphere. Specimens were held in specially designed frames which permitted free gas flow and applied a 1000 psi stress to each specimen individually during the test. Figure 1 illustrates a furnace and a gas corrosion frame.

Initial screening subjected each alloy to a 1000-hour, 1750F exposure in both air and the nitrogenous atmosphere. Following this exposure, specimens were weighed and then sectioned and examined microscopically. Some were tensile tested to evaluate strength and ductility changes. Table 4 tabulates weight changes and corrosion penetrations measured on the various specimens tested.

The typical microstructures upon which these corrosion measurements were made are shown in Figures 2-7. These show

the microstructures of the alloys both before and after the nitrogen exposure.

Test Results

The microstructures after exposure to air were similar to those shown in the above mentioned figures. The major difference noted was that the nitride penetrations in Hastelloy R-235, Inconel X, and Inconel 702 were less severe. Hastelloy X and Inconel showed slightly heavier oxidation.

Hastelloy X in the as-received condition (solution heat-treated at 2150F) shows some carbides uniformly distributed across the microstructure. After exposure, additional second phase formation occurred, but no grain growth was observed. Only a thin, tight oxide film could be observed with scattered internal oxidation sites.

Inconel showed pronounced grain growth at the interior of the specimens. Intergranular oxidation was observed on the surface.

TABLE 2—50-Hour Creep-Rupture Strength at 1750 F

Alloy	Rupture Stress, psi
Hastelloy R-235.....	> 9000
Hastelloy X.....	> 9000
Inconel.....	> 9000
Inconel X.....	7000
Inconel 702.....	5000
Inor 8.....	3000

TABLE 3—Elongation of Nickel Alloys* During 1000-Hour Creep Testing at 1750 F, 2000 psi Stress

Alloy	Elongation, Percent
Hastelloy R-235.....	1.4
Hastelloy X.....	2.2
Inconel.....	16.8**
Inconel X.....	35.0
Inconel 702.....	26.1

* Inor 8 was not available at the time these tests were performed.
** 1000 psi stress.

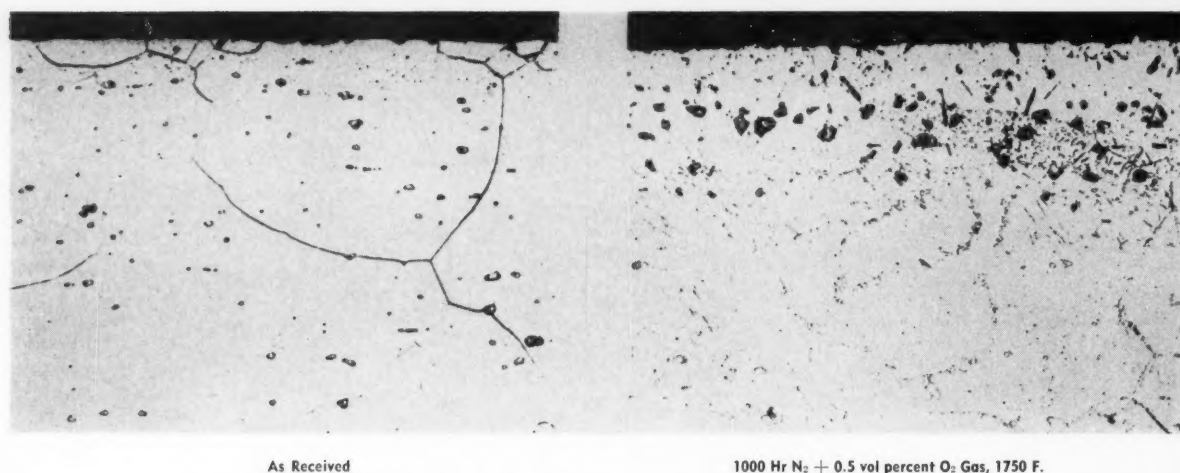


Figure 6—Hastelloy R-235 before and after exposure. Approximately 200X.

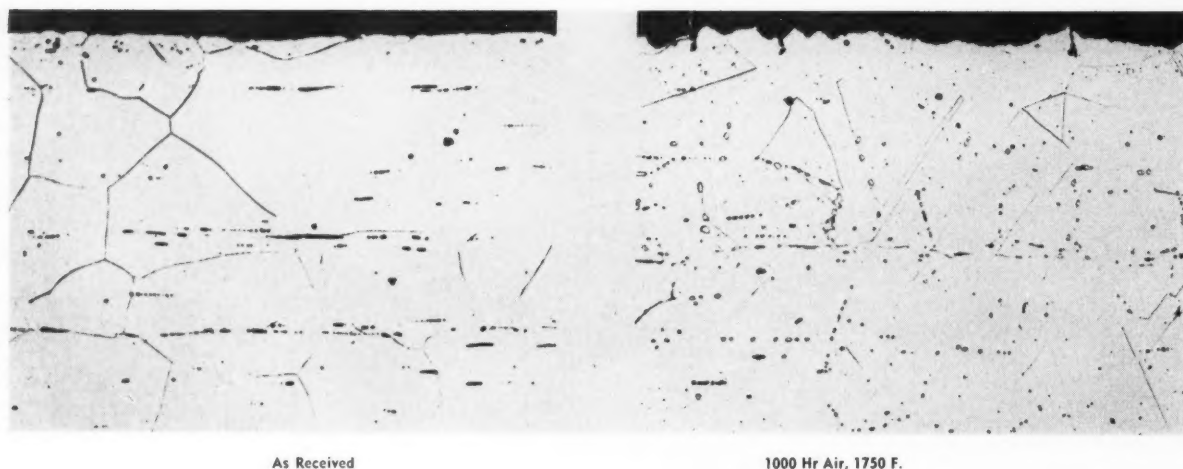


Figure 7—Inor 8 before and after exposure. Approximately 200X.

Inconel X was more severely affected by exposure. Intergranular oxidation was more pronounced and, in addition, a heavy precipitate of titanium and aluminum nitrides occurred at the surface. These titanium and aluminum constituents are present for precipitation hardening. However, because the testing temperature is above the precipitation hardening range, large grain growth occurred.

Inconel 702 was similar to Inconel X in that a fine precipitate of nitrides occurred near the surface. Intergranular oxidation also occurred. Large grain growth was observed.

Hastelloy R-235 showed a similar precipitate of nitrides along the surface. Severe internal oxidation also occurred near the surface. A continuous precipitate was noted along the grain boundaries.

Inor 8 showed poor resistance to pitting. This is probably due to the low chromium content of the alloy. A carbide precipitate similar to that observed in Hastelloy X, another molybdenum-containing alloy, occurred in the microstructure.

TABLE 4—Corrosion of Nickel-Based Alloys at 1750 F in 1000 Hours

Alloy	ATMOSPHERE			
	200 psi N ₂ + 0.5 O ₂		300 psi Air	
	Maximum Penetration, Inch	Unit Wt. Change, gms/cm	Maximum Penetration, Inch	Unit Wt. Change, gms/cm
Hastelloy X.....	0.0010	+0.00057	0.0015	+0.00165
Inconel.....	0.0005	+0.00098	0.0009	+0.00205
Inconel 702.....	0.004	+0.00084	0.0015	+0.00262
Inconel X.....	0.004	-0.00092	0.003	+0.00322
Hastelloy R-235.....	0.006	+0.00162	0.004	+0.00273
Inor 8.....	.....	.....	0.002	-0.0156

The effects of exposure in 200 psi N₂ + 0.5 O₂ upon mechanical properties is tabulated in Table 5.

This table illustrates that Hastelloy X, Hastelloy R-235 and Inconel lose strength and ductility with exposure, while Inconel 702 gains strength and loses ductility.

The ductility loss in Hastelloy X is attributed to the reorientation of carbides within the structure and penetration of nascent nitrogen into the crystal lattice. Although the loss in ductility of Hastelloy

X appears quite severe, further testing has shown these results to be on the low side. Elongations of 22-30 percent are more usually obtained. These ductilities are probably high enough to allow successful reactor operation.

Hastelloy R-235 suffers a severe loss of properties after 5000 hour exposures. Reasons for these losses were visible in the photomicrograph shown of this material after a 1000-hour exposure. After 5000 hours, the titanium and aluminum

nitride phases form almost completely throughout the metal body, rendering it extremely brittle and notch sensitive.

The loss of ductility on Inconel can be attributed to the pronounced grain growth of the alloy as well as nascent nitrogen penetration.

The improvement of strength in Inconel 702 can be expected from precipitation strengthening effects and nitride precipitation strengthening.

Based on the data obtained, an alloy was selected upon which fuel element design could be predicated. A backup alloy was also chosen for insurance. Hastelloy X was chosen as the reference alloy since it appeared to combine corrosion resistance and strength. Inconel 702 was selected as the backup alloy primarily on the basis of corrosion resistance.

The reference alloy selection described above has proven to be a satisfactory one: In tests up to 5000 hours duration this alloy has shown excellent corrosion resistance and very little loss in strength. Its greatest drawback has been the ductility losses after longer duration exposures.

Summary

This paper has described a program used in selecting a suitable high temperature alloy for nuclear fuel element use. From six alloys initially selected for screening, a primary and an alternate alloy were ultimately chosen. The characteristics considered critical for selection were corrosion resistance and strength at 1750F. Alloys showing the greatest potential for this application were Hastelloy X and Inconel 702.

DISCUSSION

Question by W. V. Ward, The International Nickel Co., Los Angeles, Calif:
Were hard nitrides present in Inconel X?

Reply by J. S. Brunhouse and G. W. Titus:

Yes, hard nitrides were present along the surface of Inconel X exposed to $N_2 + 0.5 O_2$. These particles were similar to those observed on the other precipitation hardened alloys that were studied on this program. Precipitates of this nature were not observed in the interior of the specimens. It is possible that they would form all through the metal body after longer exposure durations in this gas atmosphere.

The precipitates achieved were titanium and aluminum nitrides, and are normally very hard. Published values for the hardness of titanium nitride has been found to be 8-9 (Mohs scale).

**TABLE 5—Short-Time, Room Temperature Tensile Strength Alloys
Exposed to 1750 F 200 psi $N_2 + 0.5 O_2$**

Alloy	Exposure Time	Ultimate Tensile Strength, psi	0.2 Percent Offset Yield Strength, psi	Percent Elongation
Hastelloy X.....	Unexposed	110,550	66,060	45.0
Hastelloy X.....	Unexposed	117,400	66,400	41.0
Hastelloy X.....	2500 hours	107,350	75,980	22.0
Hastelloy X.....	5000 hours	94,340	55,190	19.0
Hastelloy X.....	5000 hours	89,720	.....	11.0
Hastelloy R-235.....	Unexposed	120,740	78,190	45.0
Hastelloy R-235.....	5000 hours	47,420	.....	*
Hastelloy R-235.....	5000 hours	66,150	.....	1.0
Inconel.....	Unexposed	89,500	33,890	46.0
Inconel.....	2500 hours	71,800	16,600	40.0
Inconel.....	5000 hours	71,500	19,500	40.0
Inconel 702.....	Unexposed	102,910	46,510	57.0
Inconel 702.....	Unexposed	108,200	43,800	58.0
Inconel 702.....	2500 hours	123,560	77,300	25.0
Inconel 702.....	5000 hours	114,770	65,340	28.0
Inconel 702.....	5000 hours	114,710	.....	25.0

* Fracture outside gauge length.

Hardness values of these particles have not been measured here since this particular point did not concern us in our investigation.

Questions by J. E. Draley, Argonne National Laboratories, Argonne, Illinois:

1. From what reference source did you get the composition of the gas used in these tests?

2. What is the effect of air on corrosion in this gas?

Reply by J. S. Brunhouse and G. W. Titus:

1. The gas composition was originally developed by Battelle Memorial Institute. (see BMI-1361).

2. I do not fully understand the question but will guess at the question's meaning. The effect of adding air to the 99.5 vol percent $N_2 + 0.5$ vol percent O_2 would be to increase the oxygen content of the gas. We do not know the effect of oxygen contents other than 0.5 vol percent and 20 vol percent (air). However, the difference in effect between the two in Hastelloy X in corrosion penetration is quite minor. Air results in a slightly greater frequency of internal oxide penetration and a thicker oxide film. On other alloys (R-235, Inconel X, Inconel 702), the quantity of precipitate is reduced as oxide film thickness increases. Allow me to point out that the oxide film itself on most of these alloys is only about 0.0005 to 0.001 inch in thickness. This is observable in the photomicrographs attached to the paper.

Comment by Warren E. Berry, Battelle Memorial Institute, Columbus, Ohio:

As the authors mentioned, the nitrogen-0.5 volume percent oxygen atmosphere was used in a corrosion program conducted at Battelle Memorial Institute. The purpose of the program was to study the corrosion behavior of austenitic stainless steels in nitrogen at temperatures of 1650 to 1800 F. It was found that nitriding of the stainless steel was inhibited by small additions of oxygen or water vapor to the gaseous nitrogen. The minimum corrosion rate occurred at 0.5 volume percent oxygen. Less than 0.5 percent oxygen apparently was insufficient to form a protective film while more than 0.5 percent oxygen resulted in oxidation of the stainless steel.

Reply by J. S. Brunhouse and G. W. Titus:

Mr. Berry's comments are, of course, quite true. A complete description of this investigation can be found in BMI 1361 entitled "Corrosion of Stainless Alloys in High Temperature Nitrogenous Environment" by D. L. Keller et al. It should be noted, of course, that their program was based upon AISI 316 and 318 stainless grades. In our experimentation with nickel based alloys, sensitivity to oxygen contents greater than the 0.5 vol percent O_2 level was not noted. Corrosion rates in air and 0.5 vol percent were not greatly different. In any case, Battelle's originally established minimum oxygen level has remained quite valid. Higher oxygen contents do not appear to significantly affect the corrosion rates of the materials tested on our program.

**Any discussion of this article not published above
will appear in December, 1961 issue.**

Effect of Acid Volume and Inhibitor Quantity On Corrosion of Steel Oil Field Tubing in Hydrochloric Acid*

By WILLIAM E. BILLINGS and DAVID MORRIS

Introduction

CHEMICAL INHIBITORS and their effect on corrosion in acid media have been studied ever since 1872 when it was reported that gelatin, bran, and glue extracts inhibited the dissolution of iron in acid.¹ Controversy still exists over many phases of inhibitor theory, but it is now generally agreed that all inhibitors do not function in the same manner.

Inhibitors may be generally classified into three categories: the cathodic type which acts on the cathodic sites of the metal surface, the anodic type which blocks the anodic portions, and the general type which reacts with or is adsorbed generally over the metal surface.

Inorganic salts of arsenic and antimony are usually referred to as being cathodic in their action.^{2, 3, 4} Examples of anodic inhibitors include phosphates,⁴ chromates,² and silicates.³ Common organic inhibitors such as aniline, pyridine, thiourea, etc. are probably adsorbed generally, perhaps with emphasis on the anodic areas.^{5, 6, 7}

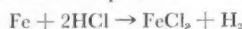
Hydrochloric Acid Corrosion in Oil Wells

Inhibited hydrochloric acid sometimes becomes trapped between tubing and casing during the course of an oil or gas well acidizing treatment. Calculations showing acid volume to steel surface area under downhole conditions indicate there is not enough acid present to seriously damage tubing if (a) corrosion is uniform and (b) corrosion stops when acid has been completely converted (theoretically) to ferrous chloride. In this connection, see Part 1 of the Appendix.

Severe corrosion can nevertheless occur if acid is allowed to remain trapped downhole because a variety of corrosive conditions may exist when hydrochloric acid is present. At least one instance has been reported wherein spent acid, contaminated with hydrogen sulfide and formation water, was responsible for the partial destruction of downhole tubing.⁸ Some of the common types of corrosion which might be expected with hydrochloric acid are as follows:

(1) Ordinary acid attack

This is the type of chemical action ordinarily connected with acids and metals. It is best exemplified by the classical oxidation-reduction equation:



(2) Concentration cells

These may be of two types, the first causing corrosion because of varying activity of metal surfaces. (See Part 2

Abstract

Several different types of corrosion on downhole tubing in the presence of hydrochloric acid are discussed. It is shown that ordinary acid attack in most instances is not sufficient to cause failure. Corrosion rates of J-55 oil field tubing were determined at several different temperatures with inhibited 15 percent hydrochloric acid. Ethoxylated rosin amine, dibutylthiourea, hexynol, and an arsenic containing compound were used as inhibitors. The effect of different acid volume to coupon surface area relationships on corrosion rate with the above inhibitors is shown. Also included is a nomograph for corrosion rate calculations. The results are tabulated on a corrosion rate versus test time basis.

4.3.2, 5.8.2

of the Appendix). This condition is thought to exist when a joint of new tubing is coupled into a string of old tubing. The old tubing, having a dense film of corrosion products on its surface, causes it to be cathodic with respect to the new joint. The result is that the new tubing is corroded much faster than the old.

The second type of concentration cell is that which can cause corrosion because of varying activity of solution next to the same metal surface. (See Part 3 of the Appendix). If the tubing surface is uniform, but the ferrous ion concentration in solution at one point is different from the ferrous ion concentration at some other point, it is possible for current to flow, the anode being the area at which the ferrous ion concentration is lower.

These are but two of the theoretical corrosion problems which may exist when hydrochloric acid is trapped next to downhole tubular goods. Galvanic corrosion,⁹ stray ground currents⁸ and hydrogen embrittlement¹⁰ are other factors which may contribute to corrosion problems. These illustrations do show, however, that other factors besides common acid attack must be considered when the use of hydrochloric acid has resulted in the destruction of downhole tubing.

Acid strength,¹¹ wetting agents,¹² foreign ions,^{8, 13, 14, 15} coupon preparation,¹⁶ inhibitor concentration,^{17, 18, 19} temperature,^{20, 21} time,^{22, 19, 23} and pressure²⁴ are some of the factors which have been studied with reference to the corrosion of metal in inhibited acid. For the most part these studies were conducted with a relatively large excess of acid present with respect to the amount of steel surface area exposed. The opposite is true when acid becomes trapped between tubing and casing during an acidizing treatment. Although Bialosky²⁵ worked with salt water and mild steel along this line, little has been published concerning these "limited acid-excess steel" conditions. This study is an attempt to show the effect of different acid volume to coupon surface



Morris

Billings

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WILLIAM E. BILLINGS is a chemist with the Halliburton Co., Duncan, Oklahoma. His experience includes two years research in HCl inhibitors and in acid corrosion problems involving oil field equipment. He has BA and MS degrees from Oklahoma State University.

area ratios on the corrosion of J-55 tubing steel in inhibited hydrochloric acid.

Experimental Procedure

Inhibitors

The four inhibitors evaluated in this study were chosen not only for their chemical composition but also because they covered a range of inhibiting efficiencies in 15 percent hydrochloric acid. Arsenic, hexynol, rosin amine and dibutylthiourea were chosen.

The arsenic inhibitor used was a commercial arsenical solution.⁽¹⁾ Arsenic was chosen because of its classification as a cathodic inhibitor, and because it is a very efficient high temperature acid inhibitor.

Hexynol⁽²⁾ (1-hexyn-3-ol) is a secondary acetylenic alcohol. Hexynol is probably a "general type inhibitor" and was chosen for use because of the acetylenic group present on the end of the molecule. The commercial use of acetylenic alcohols as acid inhibitors is relatively new, having been used only three or four years in this country. However, their acid inhibiting tendencies have been known for many years. Many of the acetylenics, including hexynol, are efficient high temperature inhibitors.

(1) Obtained from Halliburton Company, Duncan, Oklahoma.

(2) Hexynol used for these tests was obtained from Air Reduction Chemical Company, 150 East 42nd Street, New York 17, New York.

* Submitted for publication October 6, 1961. A paper presented at a meeting of the South Central Region, National Association of Corrosion Engineers, Tulsa, Oklahoma, October 25-28, 1960.

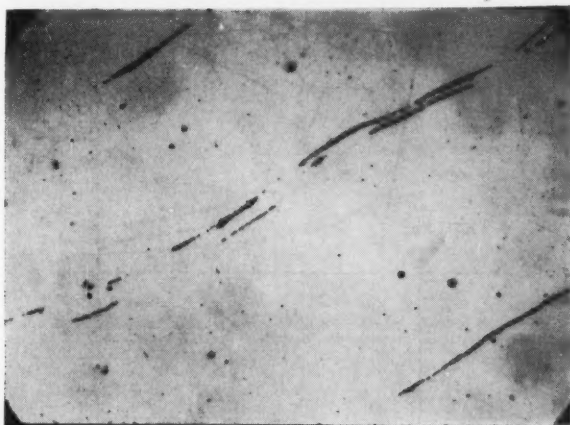


Figure 1—Nonmetallic inclusions in polished J-55 tubing. Approximately 375X.

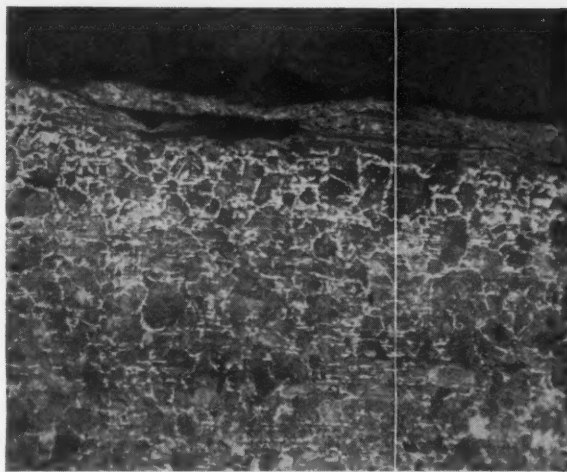


Figure 2—Lap in J-55 tubing. Nitric etch, approximately 200X.

The rosin amine inhibitor⁽³⁾ used was made by reacting 5 moles ethylene oxide with 1 mole rosin amine, then adding an additional 15 percent (by weight) rosin amine. The resulting condensate was diluted 30 percent with isopropyl alcohol. This solution has been used commercially for several years and is generally accepted to be a good acid inhibitor at moderate temperatures. Rosin amine is a general type inhibitor and was chosen because of its amine group.

Dibutylthiourea⁽⁴⁾ (1,3-dibutylthiourea) is one of the older commercial acid inhibitors and is still used in many types of applications. It is a general inhibitor and was selected because it contained a carbon-sulfur bond in the molecule along with the amine nitrogens.

Acid Volume-Coupon Surface Area Relationship

The surface area of all the coupons used was the same, consequently it was necessary to alter acid volumes in order to obtain different acid to surface area relationships. Three series of tests were conducted: limited volume, intermediate volume, and excess volume.

In the limited volume series, 10 milliliters acid was used per square inch of coupon surface area. This quantity of acid per coupon was picked to conform roughly to the volume-surface area ratios existing in the annular space between 2½ inch tubing and 5½ inch casing. This particular ratio was chosen as being representative of situations where acid becomes trapped behind tubing in an oil or gas well.

Acid quantity per coupon for the intermediate tests approximately duplicated volume-area relationships inside 6 inch line pipe; this value was chosen because it is typical of many pipeline cleaning operations. Actual acid volume used was

25 milliliters per square inch of coupon surface area.

Acid volume-coupon surface area relationships for the excess acid test series approximated conditions existing inside 12-inch pipe. The quantity of acid present in these tests was 90 milliliters per square inch of coupon surface area. This acid quantity was sufficient to completely dissolve the coupon.

Coupon Description

Test specimens were milled from a joint of 2½ inch J-55 tubing, the upsets plus 6 inches on each end of the joint not being used. Each finished coupon measured approximately 1½ inches by 1½ inches by ⅜ inch. Total surface area, including edges, measured 5 square inches.

Chemical analysis of the steel showed it to fit under SAE 1051 specifications. The analysis was as follows: carbon—0.46 percent, manganese—1.11 percent, sulfur—0.02 percent, phosphorous—0.03 percent. Hardness of the steel ranged from RC-13 to RC-15.

Microscopic examination of four sample coupons taken at random from the stock supply showed the presence of a large number of nonmetallic inclusions on the coupon surfaces. A typical example is shown in Figure 1. A lap, probably formed during piercing, was noted in one of the samples (Figure 2).

Detailed Procedure

Temperature control for the corrosion tests was effected by using water or oil baths. A thermoregulator and stirring motor in each bath kept temperatures constant to ± 1 degree F.

Inhibited 15 percent hydrochloric acid made from reagent grade⁽⁵⁾ acid and tap water was used as the corrodent in all tests; strength of the prepared acid varied from 14.8 to 15.2 percent HCl by weight. An analysis of the water and the hydrochloric acid used is listed in Table 1. With the exception of arsenic, each inhibitor was mixed with the acid immediately prior to starting a test. Arsenic

TABLE 1—Chemical Analysis of Tap Water and Hydrochloric Acid Used for Corrosion Tests

	Tap Water	Hydrochloric Acid
pH.....	7.53	Not Determined
Calcium.....	69	Nil
Magnesium.....	25	Nil
Sodium.....	10	0.5
Chlorides.....	17	423,000
Sulfates.....	136	1
Bicarbonates.....	158	Nil
Free Chlorine.....	Less than 1	Nil
Total Dissolved Solids.....	415	4
Iron.....	Nil	0.1
Specific Gravity.....	1.000 @ 76 F	1.188 @ 76 F

inhibited acid was made by mixing inhibitor with tap water and adding concentrated acid until 15 percent HCl was obtained.

Coupons were prepared for testing by the following stepwise procedure:

1. Sandblasted with 40-60 Ottawa sand to a uniform gray finish, and checked to make sure all mill scale is removed.
2. Pickled for one hour in uninhibited 10 percent hydrochloric acid.
3. Neutralized with 5 percent sodium carbonate.
4. Rinsed thoroughly with hot tap water and dried with a soft cloth.
5. Polished with a steel wire wheel on electric grinder.
6. Washed with ethyl alcohol.
7. Stored in desiccator until needed.

Beakers containing the proper quantity of inhibited acid were placed in baths and brought to test temperature. Each coupon was weighed on an analytical balance, and soaked in charcoal filtered kerosene for 30 seconds before being placed into the preheated test acid. Coupon holders made from thin glass rods were used to keep coupons exposed to the bulk of the acid during the test period. Also, glass covers were used as lids to minimize evaporation losses.

Coupons were thoroughly cleaned with a commercial scouring powder and wire brush at the end of a test. When arsenic

⁽³⁾ This inhibitor, called Cronox 0515A, was obtained from Aquaness Corporation, 2005 Quitman Street, Houston, Texas.

⁽⁴⁾ Dibutylthiourea was obtained under the trade name "Inhibitor 225" from Pennsalt Chemical Corporation, 3 Penn Center, Philadelphia, Pennsylvania.

⁽⁵⁾ Hydrochloric acid, "Baker Analyzed" Reagent.

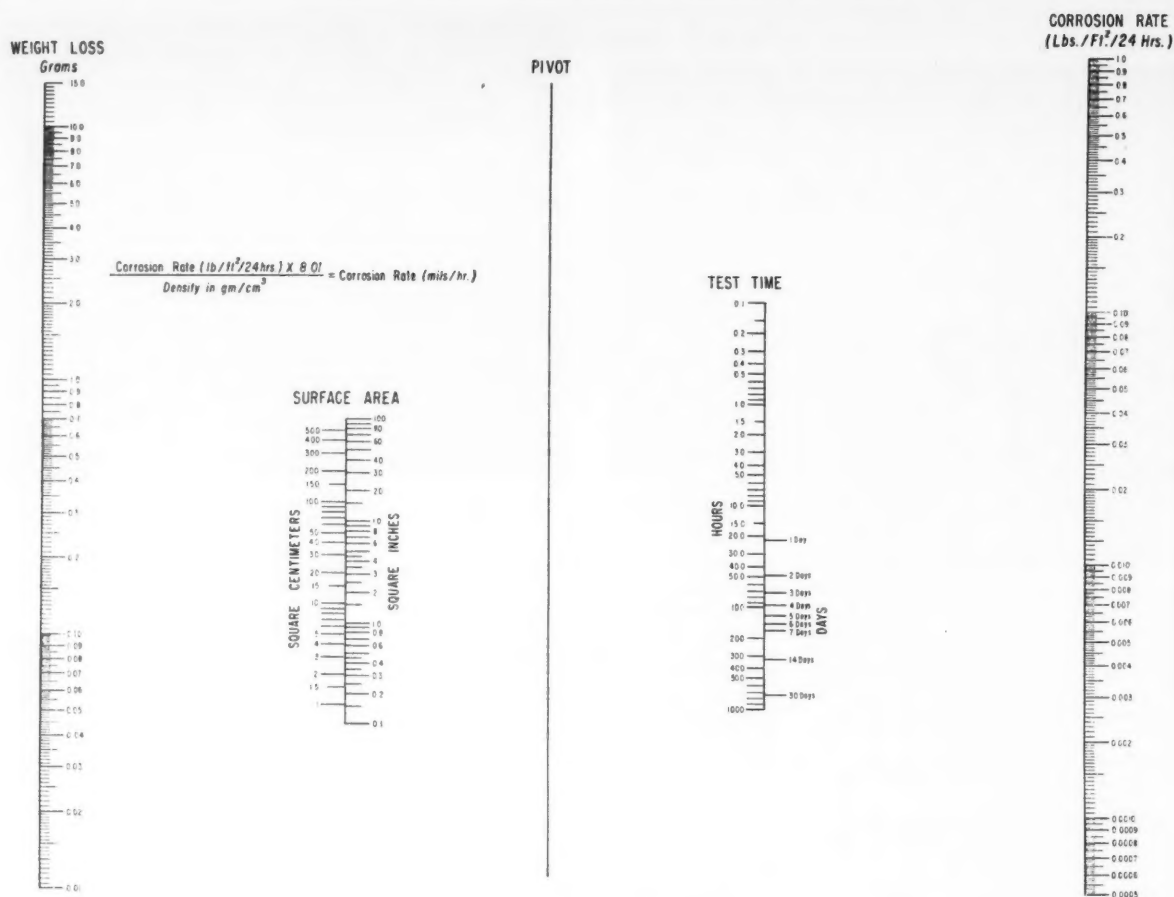


Figure 3—Nomograph for calculating corrosion rates.

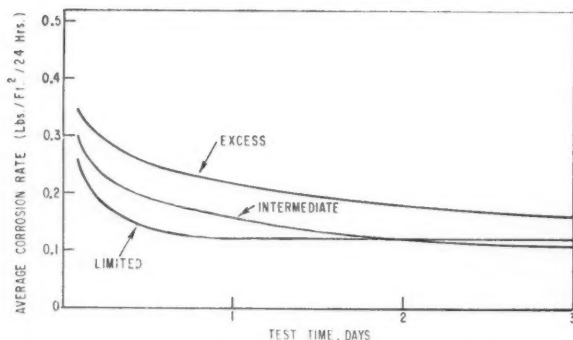


Figure 4—Average corrosion rates with no inhibitor added (100 F.) Material was J-55 tubing in 15 percent HCl.

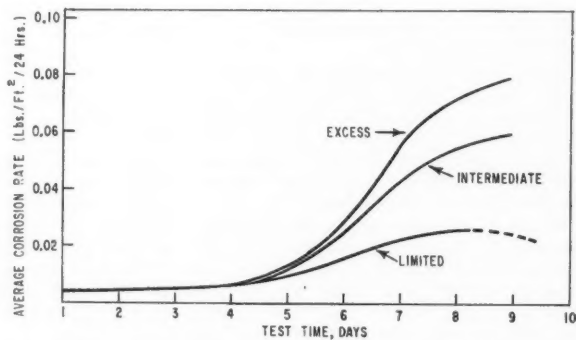


Figure 5—Effect of 0.05 percent ethoxylated rosin amine inhibited at 100 F on J-55

was used, the coupons were also boiled in 1 percent sodium dichromate. This step could probably have been deleted since it made no difference in weight loss. After scrubbing, the coupons were washed in hot water, dried with a soft cloth, washed in alcohol, and reweighed.

It was anticipated that such an extreme cleaning procedure might cause considerable weight loss due to abrasion. Actually, about 1 milligram of steel was lost due to cleaning. This loss in weight was insignificant compared to the weight loss due to acid corrosion and was ignored.

Corrosion rates were calculated from the average weight losses. A nomograph was prepared to facilitate corrosion rate calculations (Figure 3).

Results

Results of the corrosion tests are shown in Figures 4-18. Each graph shows the data obtained with limited, intermediate and excess acid volume to coupon surface area ratios with a given inhibitor at one temperature and one inhibitor concentration. The ordinate of each graph shows the average corrosion rate obtained

with a corresponding test time as determined by the abscissa. Thus, on Figure 4 it is seen that the average metal loss per unit area per unit time of J-55 tubing in limited 15 percent hydrochloric acid at 100 F is 0.12 for a 2-day test period. It should be emphasized that the ordinates of the graphs do not represent the first derivative (dy/dt) of weight loss with respect to time.

Due to the difficulty in obtaining strict reproducibility and good duplication of weight losses, small differences were

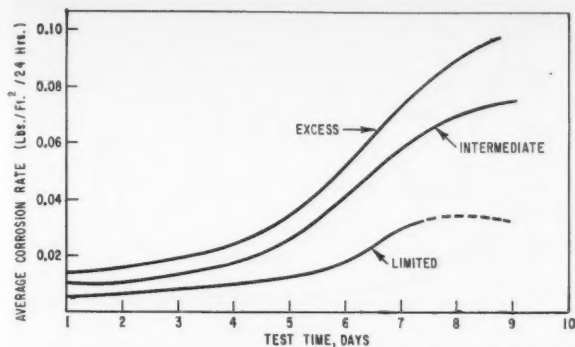


Figure 6—Effect of 0.1 percent ethoxylated rosin amine inhibited HCl at 100 F on J-55 corrosion rates. Dashed portion of curve indicates extrapolated data.

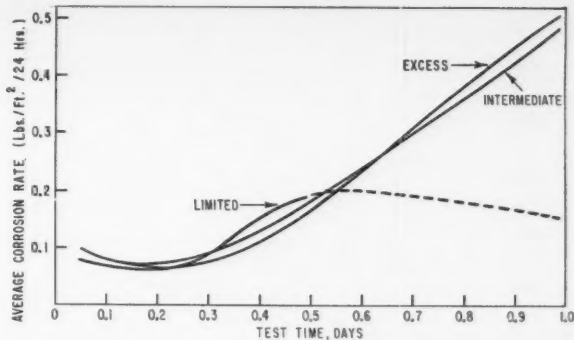


Figure 7—Effect of 0.1 percent ethoxylated rosin amine inhibited HCl at 150 F on J-55 corrosion rates. Dashed portion of curve indicates extrapolated data.

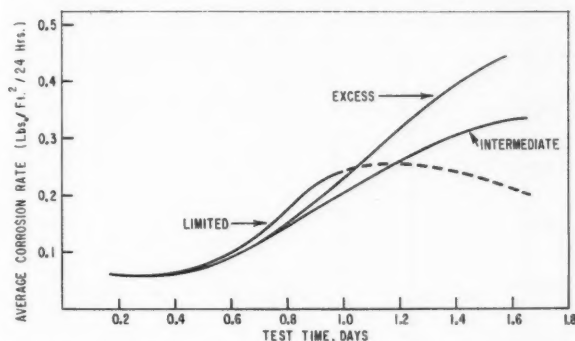


Figure 8—Effect of 0.2 percent ethoxylated rosin amine inhibited HCl at 150 F on J-55 corrosion rates. Dashed portion of curve indicates extrapolated data.

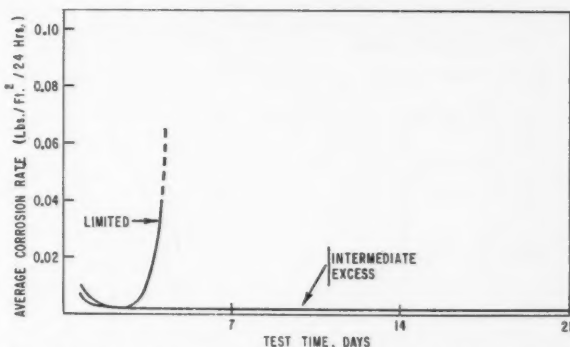


Figure 9—Effect of 0.05 percent hexynol inhibited HCl at 100 F on corrosion rates of J-55. Dashed portion of curve indicates extrapolated data.

ignored when interpreting the data. It is felt this difficulty was due in large part to the metal specimens used. When using arsenic and hexynol, good reproducibility was achieved until the inhibitor ceased to be effective, at which time varying rates were obtained.

Reproducible results were not obtained with thiourea on tubing steel. This was probably due to the slow solubility of the inhibitor and to the nature of the steel specimens. Because of this it was not possible to derive positive conclusions concerning the relationship between corrosion rate and acid quantity-coupon surface area when using this inhibitor.

Figure 4 shows the corrosion rates obtained in uninhibited hydrochloric acid. It can be seen that corrosion rates were highest in the excess acid series. Since the acid strength remained at a relatively high level in the excess acid series for a longer period of time, these results were not unexpected.

Figures 5 through 8 show the results using ethoxylated rosin amine as an inhibitor. During the first several hours of exposure the curves were essentially flat indicating corrosion rate to be more or less constant. The inhibitor finally ceased to function properly and a rather sharp increase in corrosion occurred until the acid was spent. The length of time it took for this increase in corrosion rate to occur was independent of the total quantity of inhibited acid in contact with a coupon.

Figures 9 through 14 illustrate the data obtained using hexynol inhibited acid. At first, the curves dipped slightly until a minimum plateau was reached where corrosion rates stayed constant for a period of time. At longer test times there was a radical departure from the results obtained with ethoxylated amine. In almost every instance, curves for the limited acid series showed a positive deflection in a shorter period of time than did curves for the excess acid series. The intermediate curve series invariably fell between the two. The only exception to this phenomenon is shown in Figure 10 and it is believed these data would have shown a similar effect had the tests been longer. No references could be found in the literature which satisfactorily explain this peculiarity. Apparently both inhibitor concentration and total quantity of inhibitor in the solution affect coupon behavior in inhibited hydrochloric acid, at least with certain inhibitors.

Figures 15 through 18 show the corrosion pattern with arsenic inhibited acid. Practically the same peculiar results were obtained with arsenic as were obtained with hexynol, with the limited series showing an increase in corrosion before the intermediate or excess series. At the present time no explanation can be given why this phenomenon occurs; however, further study is planned.

Since there is no standard method in use at the present time for testing the

performance of hydrochloric acid inhibitors, and since testing procedures often vary, the phenomenon of more rapid coupon deterioration under limited acid-excess steel conditions may help explain some of the incongruities concerning the effectiveness of certain inhibitors.

Summary

It was shown that when 1-hexyn-3-ol or arsenic was used as an inhibitor, J-55 steel coupons in contact with small volumes of inhibited hydrochloric acid were corroded faster than similar coupons immersed in larger volumes of the same acid. This phenomenon was not observed when acid was inhibited with ethoxylated rosin amine. Work is planned to determine the reason this condition exists with certain inhibitors. Apparently inhibitor efficiency can be a function of total inhibitor quantity in the corrodent as well as being a function of inhibitor concentration.

Acknowledgment

The authors acknowledge the assistance of John Knox and Calvin Saunders for their helpful suggestions and discussions. They also wish to thank the Halliburton Company for permission to publish this article.

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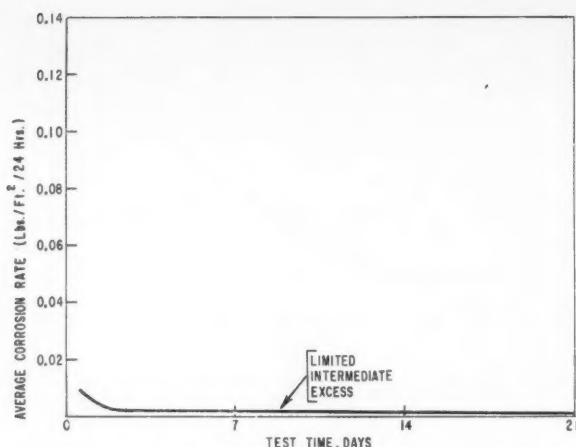


Figure 10—Effect of HCl inhibited with 0.1 percent hexynol at 100 F on J-55 corrosion rates.

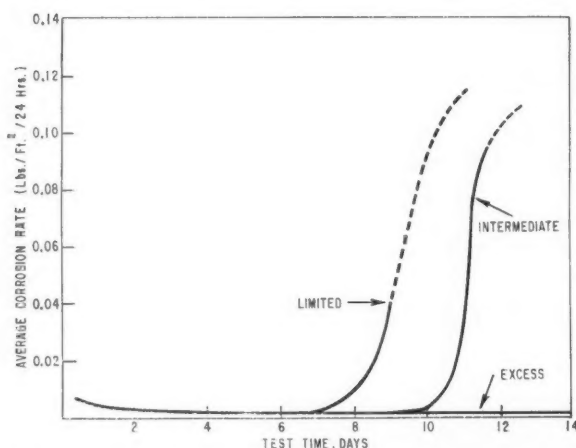


Figure 12—Effect of HCl inhibited with 0.2 percent hexynol at 150 F on J-55 corrosion rates. Dashed portion of curve indicates extrapolated data.

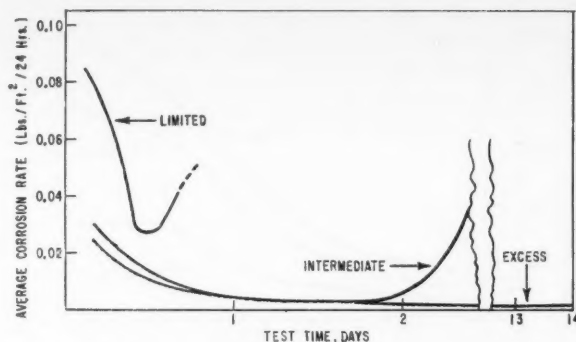


Figure 11—Effect of HCl inhibited with 0.1 percent hexynol at 150 F on J-55 corrosion rates. Dashed portion of curve indicates extrapolated data.

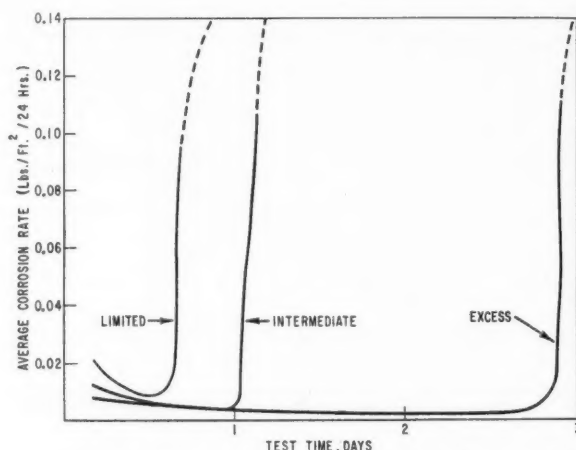


Figure 13—Effect of HCl inhibited with 0.2 percent hexynol at 200 F on J-55 corrosion rates. Dashed portion of curve indicates extrapolated data.

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APPENDIX

Part I—Amount of Corrosion Possible on Tubing by Hydrochloric Acid

For illustrative purposes, assume 2½ inch tubing is inside 5½ inch casing, and the annular space is filled with 15 percent hydrochloric acid. The amount of iron which can be dissolved, assuming (a) corrosion is uniform and (b) corrosion stops when acid has been completely reacted to form ferrous chloride, can be easily calculated.

Annular volume between tubing and casing varies from 0.55 to 0.70 gallons per linear foot, depending on the weight of casing and tubing. The value of 0.70 was chosen for these calculations. This quantity of acid can react with approximately 0.73 pounds iron. Assuming the weight of casing to be 13 pounds per foot, and the weight of tubing to be 6.4 pounds per foot, it is apparent that only about 4 percent of the steel can be dissolved.

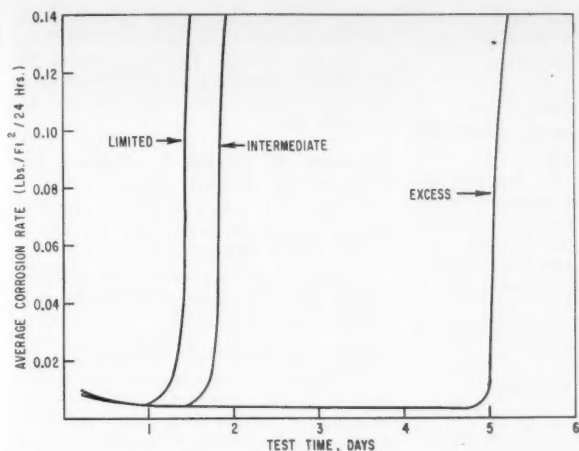


Figure 14—Effect of HCl inhibited with 0.4 percent hexynol at 200 F on J-55 corrosion rates.

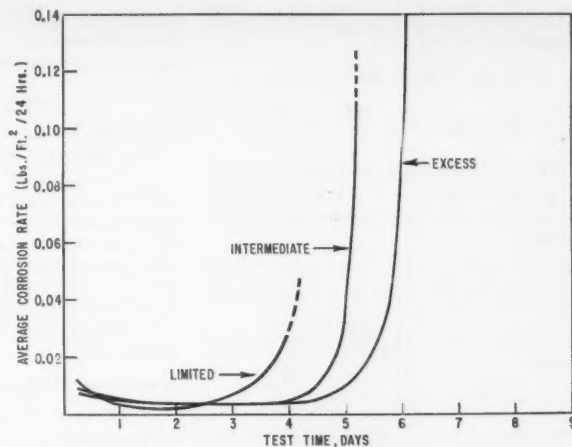


Figure 15—Effect of HCl inhibited with 0.1 percent arsenic at 150 F on J-55 corrosion rates. Concentration of arsenic is calculated on basis of arsenic metal in solution. Dashed portion of curve indicates extrapolated data.

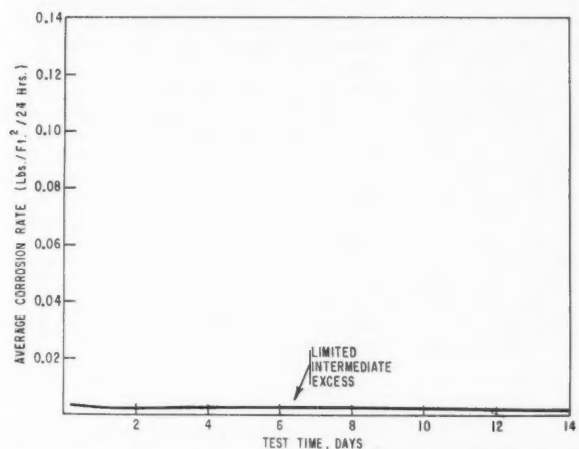


Figure 16—Effect of HCl inhibited with 0.2 percent arsenic at 150 F on J-55 corrosion rates. Arsenic concentration is calculated on basis of arsenic metal in solution.

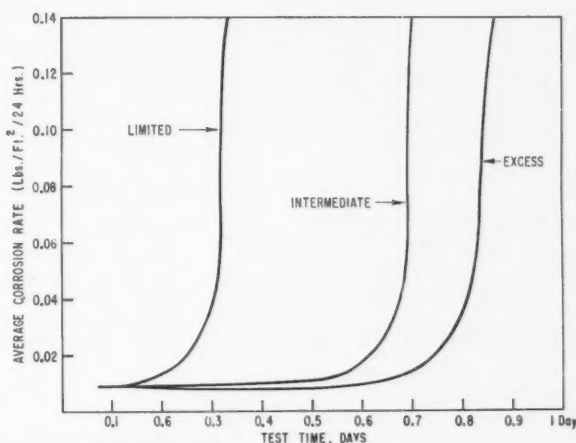
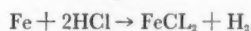


Figure 17—Effect of HCl inhibited with 0.2 percent arsenic at 200 F on J-55 corrosion rates. Concentration of arsenic was calculated on basis of arsenic metal in solution.

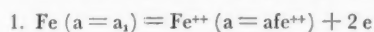
The above calculations were based on the equation



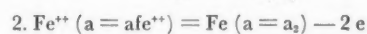
Part 2—Concentration Cells Due to Varying Activity of Metal Surface²⁶

Consider the cell
 $\text{Fe} (a = a_1) | \text{Fe}^{++} (a = a_{\text{Fe}^{++}}) | \text{Fe} (a = a_2)$
 Where a_1 represents the activity of one iron electrode, and a_2 represents the activity of the second electrode. These activities may be different because of different carbon content of steel, non-metallic inclusions, etc. Activity of ferrous ions in solution is represented by $a_{\text{Fe}^{++}}$.

Elementary cell reactions and EMF values for the two half cells are as follows:



$$E_1 = E^\circ - \frac{RT}{2F} \ln \frac{(a_{\text{Fe}^{++}})}{(a_1)}$$



$$E_2 = -\left(E^\circ - \frac{RT}{2F} \ln \frac{(a_{\text{Fe}^{++}})}{(a_2)}\right)$$

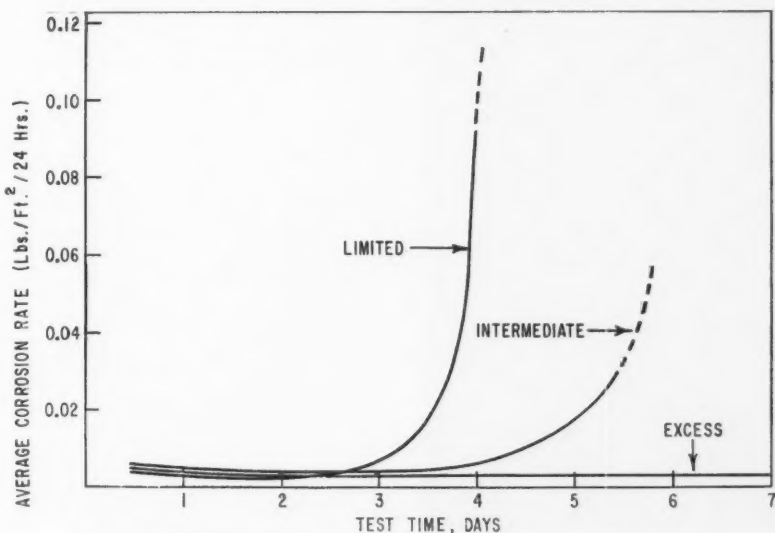


Figure 18—Effect of HCl inhibited with 0.4 percent arsenic at 200 F on J-55 corrosion rates. Concentration of arsenic was calculated on basis of arsenic metal in solution.

On combining these two equations one obtains the following:

$$Fe(a=a_1) = Fe(a=a_2)$$

$$E_1 + E_2 = E = \frac{RT}{2F} \ln \frac{a_1}{a_2}$$

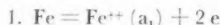
Thus, it is seen that the EMF generated in a cell of this type is a function of the differing activities between two unlike iron surfaces.

Part 3—Concentration Cells Due to Varying Activity of Solution Next to the Same Metal Surface²⁶

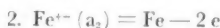
Consider next a cell of this type, namely:



Consisting of two identical iron electrodes immersed in two ferrous chloride solutions of different concentrations. If the junction potential is neglected the reactions and EMF values for the two half cells are as follows:



$$E_1 = E^\circ - \frac{RT}{2F} \ln a_1$$



$$E_2 = -\left(E^\circ - \frac{RT}{2F} \ln a_2\right)$$

On combining the two cells:



$$E_1 + E_2 = \frac{RT}{2F} \ln \frac{a_2}{a_1}$$

It is seen that the EMF value is propor-

tional to the log of the ratio of ferrous ion concentrations differing in adjacent locations on the same metal surface.

DISCUSSION

Questions by L. K. Gatzke, Shell Oil Co., Denver, Colo.:

1. It was stated that the hexynol inhibitors were good for inhibiting acids at high temperatures. What do you consider high temperature, and would you consider the hexynol inhibitors good for inhibiting 15 percent hydrochloric acid at temperatures up to 400 F?

2. What do you consider adequate acid inhibition?

Replies by William E. Billings:

1. The term "high temperature" is certainly an ambiguous one which should be clarified. The upper limit of inhibitor effectiveness (in hydrochloric acid) for the acetylenic inhibitors is somewhere below 300 F. Acid treatments could probably be carried out safely at bottom hole temperature slightly in excess of this if the downhole acid-steel contact time could be held to one hour or less. I would be hesitant to recommend any organic compound for protecting tubing grade steel in hydrochloric acid at 400 F.

2. One of the advantages in reporting data as we have in this paper is the ease with which "adequate acid inhibition" can be determined. Rates could be as high as 1-2 pounds per foot² per day if the corrosion process was uniform, although normally corrosion rates with good inhibitors are very much lower than this. We consider pitting more serious than a high but uniform corrosion rate,

and pitting is very seldom evident along the descending or flat portion of the rate versus time curve. For this reason, we consider inhibition is adequate so long as the rate versus time curve remains essentially flat.

Questions by Charles C. Nathan, The Texas Co., Bellaire, Texas:

1. Was the attack uniform or was severe pitting observed? Did the nature of the attack change with time?

2. What was the effect on inhibitor effectiveness when different metals were tested (e.g., N-80, P-105)?

Replies by William E. Billings:

1. Attack was very uniform during the period of time when corrosion rate was constant or slightly decreasing. When the corrosion rate began to increase, pitting often occurred. At the present time we believe the more efficient inhibitors eventually cause pitting to a greater degree than do less efficient inhibitors. This statement is true with the inhibitors evaluated in this paper and with certain others investigated, but not enough evidence has been gathered to formally propose such an opinion.

2. Inhibitor effectiveness usually decreases with the higher strength steels. There are many exceptions due to the very broad specifications set on oil field grade tubing. We have observed two different lots of P-110 steel which, under identical corrosive environments in inhibited hydrochloric acid, gave corrosion rates that differed by a factor of 15. For a general rule however, we have found inhibitor effectiveness highest on J-55 and lowest on P-105 and J-110.

Any discussion of this article not published above
will appear in December, 1961 issue.

New Methods of Simulating Corrosive Plant Conditions In the Laboratory*

By A. ORMAN FISHER

Introduction

THE TEMPERATURE versus corrosion properties of metals and alloys in specific environments is of great concern to the designers of chemical processing equipment. Although the proper selection of alloys is essential to the profitable operation of chemical plants, there is a surprising lack of published temperature versus corrosion data suitable for making such selection. The best information appears to be in the form of iso-corrosion charts¹ composed of generalized data compiled from many sources and obtained under varied laboratory and field conditions. Unfortunately, this information is confined almost exclusively to the more common environments such as sulfuric and nitric acids. Other data are available in the form of charts² for a wide variety of chemical environments. However, this material is also compiled from many sources, and in most cases is too general for determining a precise temperature versus corrosion parameter of an alloy in a specific environment.

Perhaps even more surprising than the lack of sufficient temperature-corrosion information is the relatively few references concerning suitable test methods for obtaining these data. This situation appears to be improving, with at least two publications^{3,4} appearing in the last two years which are directly concerned with the testing problem.

It should be stated that all laboratory equipment described in these studies was developed for the express purpose of simulating plant conditions as closely as possible and that the object of this presentation is to describe some of the most recent advances in these techniques. Particular emphasis is given to the corrosion of metals under heat transfer conditions. In all cases the plant problems are described so that the field conditions desired in the laboratory test apparatus will be known. Specific results are given for purposes of illustrating the performance of the laboratory equipment. Accordingly, the presentation of these temperature-corrosion data should be regarded merely as a secondary objective of this paper.

Modified Disc Heat Flux Apparatus

The modified disc heat flux apparatus previously described⁴ is believed to be the most suitable of those devised in the laboratory for reproducing corrosive plant conditions involving heat transfer and elevated temperatures. Both a 1-inch

Abstract

Various laboratory testing devices developed for the reproduction of corrosive plant conditions are described with particular emphasis on heat transferring surfaces. An all-glass, pressurized, heat transferring test unit capable of giving corrosive data under five different heat conditions is described in detail.

Information on specific plant problems involving both heating and cooling surfaces is given together with the test methods employed in the laboratory study. Corrosion data on various alloys in sulfuric acid, nitric acid, and other environments obtained in the laboratory equipment are included for illustrative purposes. Data on ten different alloys are given for 65 percent HNO₃ under elevated temperature and pressure conditions.

7.4.1, 3.5.9, 3.5.7, 4.3.2

and 2-inch diameter test apparatus have been used with considerable success in a number of investigations. A brief description of the 2-inch diameter unit is given below since this larger unit more closely duplicates heat transfer ranges encountered in chemical equipment.

In the 2-inch unit, heat from a 550 watt soldering iron is transmitted through a flat ground aluminum heating surface to the 2 3/4-inch by 2 3/4-inch by 1/4-inch thick metal test specimen, which in turn transfers the heat to a solution contained in a 1 liter glass, three neck flask. This flask is fitted with a 2-inch diameter glass pipe bottom outlet to which the metal test specimen is fastened by means of a standard glass pipe cast iron flange. The flask is also fitted with a glass condenser, agitator and thermometer well from which a control non-heat transferring metal specimen is suspended in the test solution. Thermocouple temperature readings are taken in the aluminum head for purposes of heat transfer calculations, and in the center of the metal heat transfer specimen.

One test unit is shown schematically

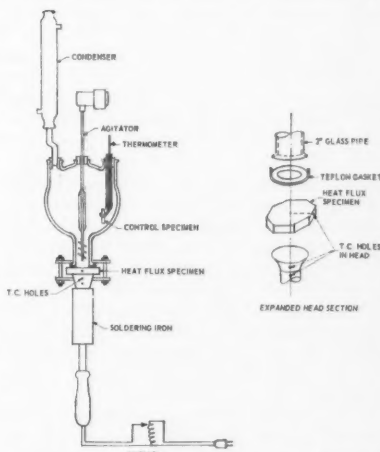


Figure 1—Schematic diagram of modified heat flux apparatus.



About
the
Author

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in Figure 1. A photograph of such a unit is shown in Figure 2. The heat transferring specimen can be heated to a maximum of about 210 C in this apparatus while the heat transfer rates can be adjusted from 5,000 to 30,000 BTU per hour, per square foot, by varying the electrical input to the soldering iron. Corrosion rates are determined by weight loss.

A typical study made in this apparatus concerned the investigation of the effect

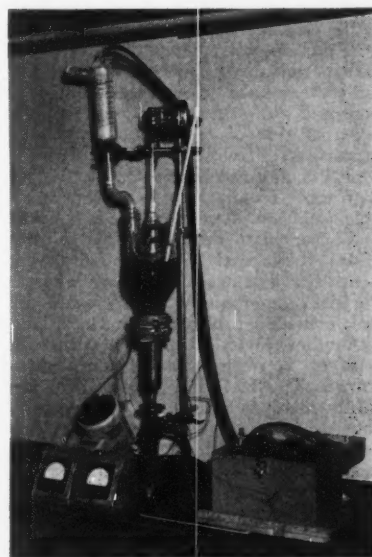


Figure 2—Photograph of modified heat flux apparatus.

* Submitted for publication September 16, 1960. A paper presented at a meeting of the North Central Region, National Association of Corrosion Engineers, Milwaukee, Wisconsin, October 19-20, 1960.

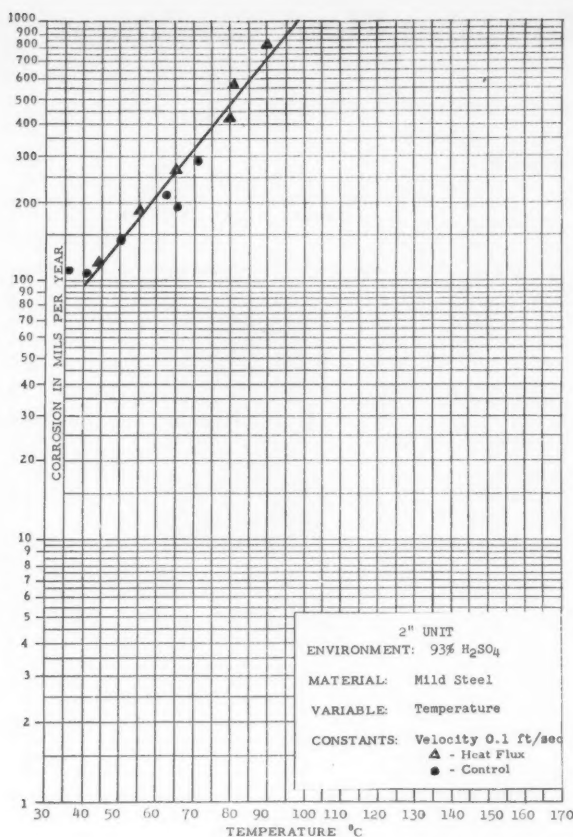


Figure 3—Effect of temperature on corrosion of mild steel in 93 percent sulfuric acid.

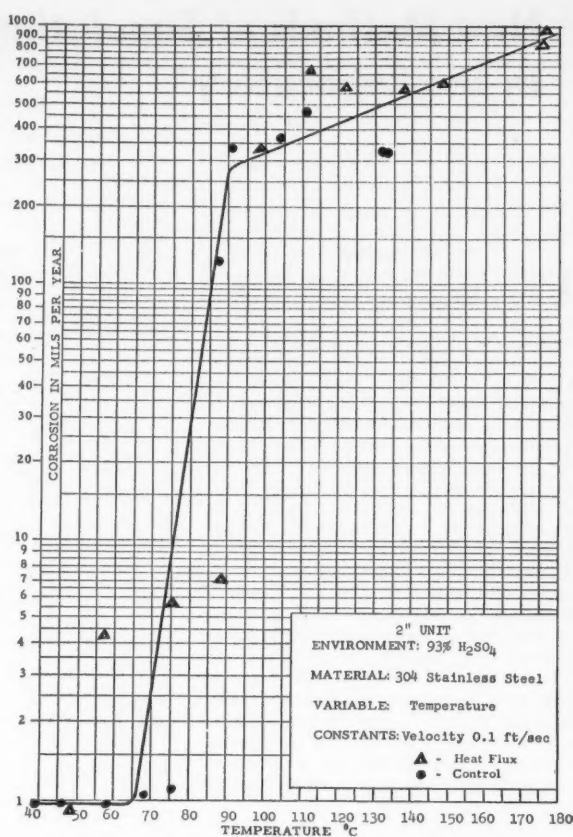


Figure 4—Effect of temperature on corrosion of Type 304 stainless steel in 93 percent sulfuric acid.

of temperature upon the corrosion of various alloys in mineral acids. Data for mild steel, 304 stainless steel and 316 stainless steel in 93 percent H_2SO_4 are plotted in Figures 3, 4, and 5. The "critical corrosion temperature" for 304 stainless steel in this study would be taken as approximately 75 C to 85 C according to the data in Figure 4. In each case the heat flux specimen temperature was obtained from the thermocouple reading in the center of the $\frac{1}{4}$ -inch thick test coupon and the control temperature was taken as that of the solution contained in the flask. It will be observed that the results of mild steel are somewhat higher than those usually recorded in the available literature. This difference is believed to be related to the fact that a velocity of 0.1 ft/sec with turbulent flow swept across the heat transfer surface whereas the data reported in the literature are usually obtained under static conditions.

Another investigation in which this type of apparatus proved useful concerned the effect of a sulfuric acid impurity in nitric acid upon the corrosion rate of various alloys under heat flux conditions. These tests were undertaken in the 1-inch diameter test units for the purpose of finding suitable materials of construction for a 70 percent nitric acid reboiler. Data are given in Table 1 for four alloys in 70 percent nitric acid

TABLE 1—Corrosion of Stainless Steels in Boiling*
70 Percent HNO_3 + 0.25 Percent H_2SO_4 Under Heat Flux Conditions
(1 Inch Unit)

Metal	Exposure, Hours	Heat Flux, BTU/hr./sq. ft.	Heat Flux, Specimen, Temp. °C	Corrosion Rate, MPY	
				Heat Flux	Control
304	24	65,000	162	74**	22**
304	24	35,000	153	44	17
304	96	20,000	140	50	26
304 ELC	24	65,000	175	70**	17**
304 ELC	24	35,000	158	35	16
304 ELC	96	20,000	140	60	30
347	24	65,000	169	69	27
347	24	35,000	153	77	17
347	96	20,000	132	54	50
Carpenter 20	24	65,000	184	24**	11**
Carpenter 20	24	35,000	158	19	9
Carpenter 20	96	20,000	141	16	9

* 120 C boiling acid temperature for all runs.

** Average of two runs.

contaminated with 0.25 percent H_2SO_4 . It can be seen that Carpenter 20⁽¹⁾ alloy, although sustaining a substantial corrosion rate, up to 24 MPY at 363 F (184 C.), is quite superior to the other alloys tested. Presumably this is because of its copper alloy content which improves corrosion resistance in sulfuric acid. All alloys showed general attack except 304 ELC which showed some areas of intergranular attack.

The reason for localized intergranular attack on the 304 ELC specimen is not known. It should be pointed out that since the 1-inch diameter units were used,

heat flux rates were of a higher magnitude, 20,000 to 65,000 BTU per hour, per square foot, than would have been obtained in a 2-inch unit under similar heat settings. In these tests, the agitation rates measured empirically for water were 0.6 and 0.1 ft/sec for the heat flux and control specimens respectively.

The above type of laboratory information is believed to be of value to both designers and users of chemical process equipment in that critical temperature conditions can be avoided in the field either by suitable process control or by substitution of more resistant alloys. Al-

(1) Trade name of Carpenter Steel Company, Union, New Jersey.

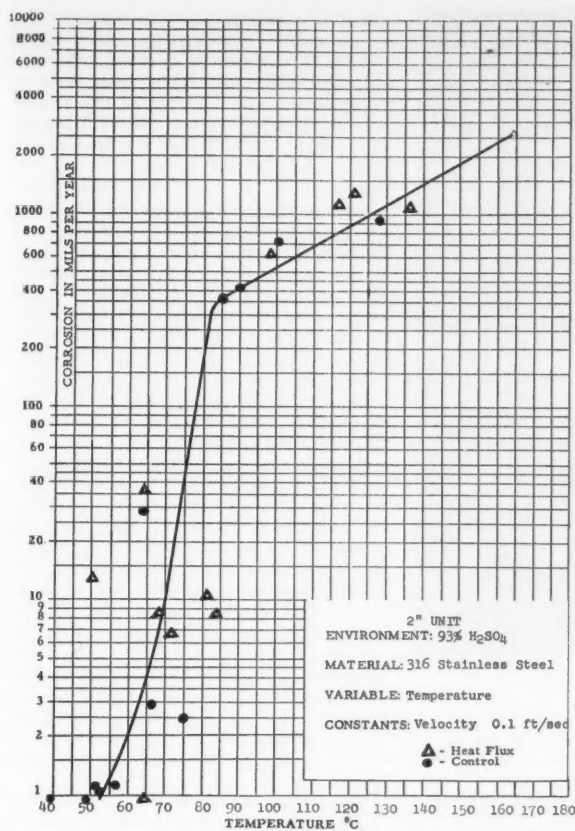


Figure 5—Effect of temperature on corrosion of Type 316 stainless steel in 93 percent sulfuric acid.

though additional alloys and environments were continually being studied for these purposes in a bank of four 2-inch test units, it soon became apparent that some field problems and conditions could not be reproduced in these units without modification. For example, problems involving temperatures greater than 210 C, pressures above atmospheric, vapor-liquid interface exposures and cooling surfaces could not be studied. Efforts were thus directed toward the development of laboratory equipment to meet these conditions.

Elevated Temperature Conditions

Repeated tube failures in a 316 stainless steel preheater in an organic chemical environment "B" led to an extensive laboratory investigation involving the influence of temperature upon corrosion. Plant operation revealed that the preheater was under-designed for the equilibrium requirements of the adjacent stripping column. As a result the preheater was operated at higher temperatures. The increased temperatures produced accelerated pitting and cratering in the outlet end of the 316 stainless steel tubes which resulted in complete penetration in a matter of six months. The inlet end of the tubes remained relatively free of attack, however, indicating temperature conditions were primarily responsible for failure. Because of space limitations and the cost of installing a

larger 316 stainless steel preheater, the feasibility of retubing the present unit with more corrosion resistant materials was investigated.

After the first few runs in the 2-inch modified disc heat flux apparatus previously described, it was evident that temperatures greater than 572 F (300 C) could not be obtained. These first trial runs did, however, reveal that 316 stainless steel was quite satisfactory up to 440 F (227 C), the highest temperature reached on the heat transfer specimen.

The experience gained from these runs in the modified disc heat flux unit proved that in order to maintain liquid temperatures of 250 to 300 C and heat flux specimens of 300 to 375 C, an auxiliary source of heat would be required. This was solved by substituting a 2-inch diameter by 12-inch long borosilicate glass pipe for the one-liter flask and winding it with resistance wire. A new glass head was also necessary for accommodating a thermometer well and a nitrogen gas inlet. Since a boiling solution was to be tested, no stirring mechanism was provided. The method of heating the heat flux specimen remained the same; however, a 304 stainless steel heating head was substituted for the aluminum head. This was necessary because of deformation of aluminum under the extreme heat conditions developed by the soldering iron. A schematic diagram of the elevated temperature apparatus is shown in Figure

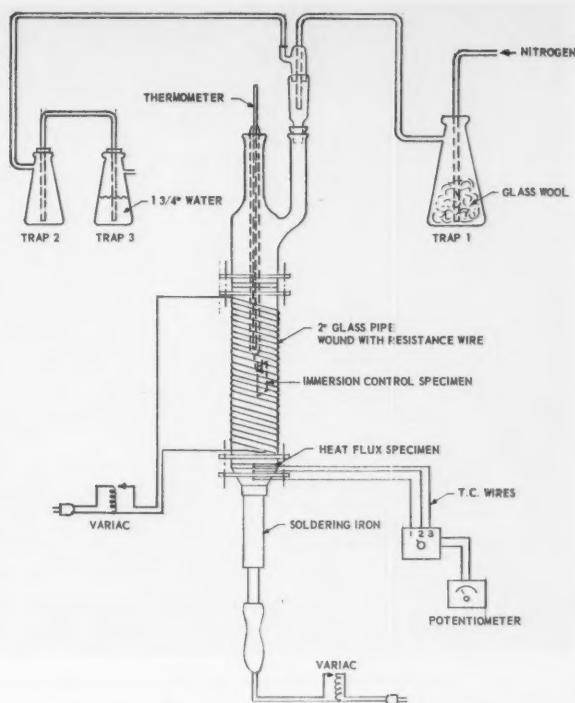


Figure 6—Schematic diagram of elevated temperature-heat flux corrosion apparatus.

TABLE 2—Cooling Water Analysis

No. 1 Water	No. 2 Water
pH = 7.0	pH = 6.7
A Reading 0.0cc of N/30 HCl	Color = 11.4
M O Reading 0.6cc N/30 HCl	Odor — Hot 2H
Color = amber clear	Odor — Cold 2D
Hydroxide (OH) 0 ppm	Turbidity 2.2 ppm
Carbonate (CO ₃) 0 ppm	Free CO ₂ 2.7 ppm
Bicarbonate (HCO ₃) 12 ppm	Alkalinity as (CaCO ₃) 7.2 ppm
Sulfate (SO ₄) 10 ppm	Chlorides 3.86 ppm
Chloride (Cl) 6 ppm	Hardness 14.9 ppm
Silica (SiO ₂) 2 ppm	Total iron .18 ppm
Calcium (Ca) 5 ppm	Manganese .005 ppm
Magnesium (Mg) 1 ppm	Nitrates None
Suspended solids est. 2 to 4 ppm	Dissolved Oxygen 11.2 ppm
Hardness as (CaCO ₃) 16 ppm	Temperature 53.2 F
Dissolved Oxygen 7 to 9 ppm	

6. A photograph of a typical unit is shown in Figure 7.

Some 32 tests were made in the elevated temperature apparatus on seven alloys. For these tests a 450 cc charge of the organic material "B" was used for each run. The test apparatus was continually purged with nitrogen at 1 3/4-inch water pressure during the entire test period. In each run a non-heat transferring control specimen was suspended in the liquid phase from a hook on the thermometer well.

Although no attempt was made to calibrate the actual heat transfer during each run, it is estimated that 15,000 to 30,000 BTU per hour per square foot was

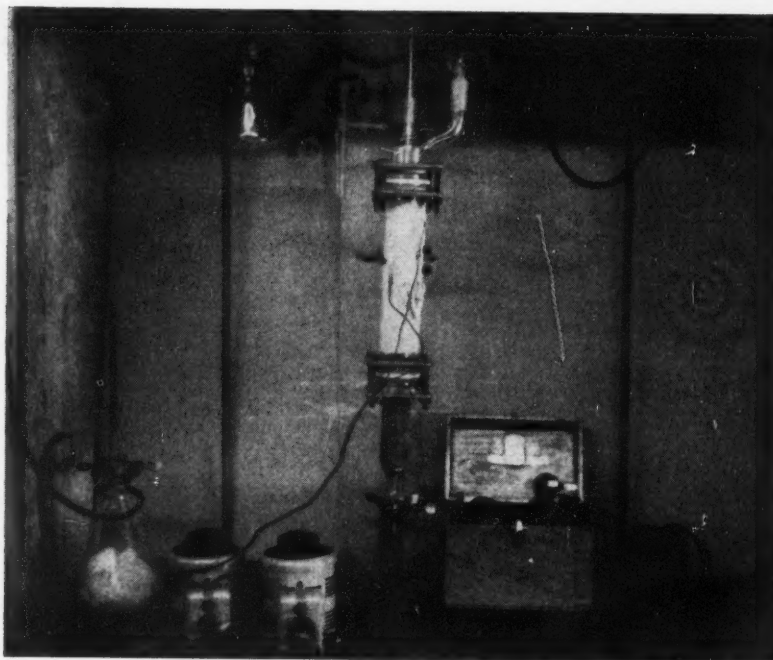


Figure 7—Elevated temperature heat flux corrosion apparatus (2-inch unit).

TABLE 3—Corrosion of A-285 Steel in Inhibited Water Pressurized Heat Flux Unit*

Inhibitor Conditions	Corrosion Rate, Mils Per Year	
	No. 1 Water 8 ppm O ₂	No. 2 Water 11 ppm O ₂
Control, No inhibitor	37.	39.
2000 ppm Inhibitor A ^a	Nil	<1.
120 ppm Na ₂ SO ₃ , activated ^b	12.	16.
440 ppm Na ₂ SO ₃ , activated ^b	28.	32.

* Water Temperature = 274 F (134 C) \approx 30 psig.

Metal heat transfer surface = 248 to 302 F (120 C to 150 C).

^a Commercial inhibitor containing approximately 1500-1700 ppm sodium nitrite plus other components, borate etc.

^b Activated with cobaltous chloride as 0.02 percent cobalt. Based on sodium sulfite.

transmitted through the heat flux specimen to the solution and approximately 140 BTU per hour per square foot was transmitted through the pipe walls to the solution. Because of the excessive heat employed, new fluorocarbon gaskets were required for every test. The duration of each run varied from 5.5 to 24 hours depending upon the corrosion rate sustained by the heat flux specimen. In the case of higher corrosion rates, an exposure period longer than 6 hours would have resulted in leaking between the gasket at the heat flux specimen.

A number of significant conclusions were obtained from this study. Perhaps the most important from an academic standpoint was the fact that the newly designed elevated temperature unit produced the same type of corrosion pattern (pitting) on the 316 stainless steel laboratory specimens as was experienced under plant conditions. The pitting was not duplicated in the standard modified disc unit. This reproduction of the type of corrosive attack introduced a considerable amount of reliability to all subsequent data that was obtained in this particular study using the elevated temperature unit.

A second conclusion concerned the

verification of the temperature sensitivity of 316 stainless steel in this environment. From a production standpoint, the most significant conclusion reached was that either Hastelloy B⁽²⁾ or titanium could be used as a replacement for 316 stainless steel (See Figures 8 and 9 for a schematic comparison of corrosion for 316 stainless steel and Hastelloy B in this environment). It can be stated that as a result of this investigation, Hastelloy B was employed for the next preheater unit. Visual examination of the Hastelloy B heat exchanger after approximately one year of service in this environment revealed no corrosive attack at the tube outlet.

Pressure Conditions

Another plant problem concerned the recommendation of an inhibitor for the prevention of rust formation in steel jackets of glass lined vessels and a number of 304 stainless steel resin kettles containing A-285 steel jackets. A gradual loss in heat transfer leading to process inefficiencies was the primary concern rather than corrosion. Uninhibited cooling water is circulated through the jackets for pur-

⁽²⁾ The term "Hastelloy" is a registered trademark of Union Carbide Corporation.

poses of regulating process temperatures in the vessels. Examination of the jackets revealed considerable corrosion deposits on the walls and the accumulation of loose scale in the bottom of the jackets which restricted water flow. Although the entire cooling water system was designed as a closed system with coolers, pumps and reservoirs, the cooling demands of the many process vessels during peak periods resulted in the introduction of large quantities of cold river water to maintain adequate cooling temperatures. The addition of oxygen saturated water aggravated the corrosion problem which in turn caused heat transfer difficulties. After the obvious corrections were made (i.e., jacket cleaning, jacket replacement, and system enclosure), the problem of mitigating possible future corrosion remained to be answered.

Laboratory equipment designed for solving this problem consisted of modifying the elevated temperature heat flux unit shown in Figures 6 and 7 so that pressures up to 30 psig (274 F) could be accommodated. It had been determined that the most unfavorable condition in the cooling jackets was 30 psig with a hot metal wall temperature of approximately 300 F. For pressurizing purposes a 1/8-inch thick 304 stainless steel plate was clamped atop the 2-inch diameter by 12-inch long borosilicate glass pipe so that a 30 psig brass blow-off valve could be incorporated into the apparatus.

A number of four hour long tests were made at 30 psig using two inhibitors and two types of cooling water. Table 2 gives the water analyses.

The temperature of the steel heat transfer test specimen was adjusted to 248 to 302 F (120 to 150 C) for each run. The time limitation of four hours was imposed by the supposition that dissolved oxygen in the water was the major contributing factor to corrosion and calculation indicated that the O₂ would be exhausted in less than 12 hours. Because of the critical nature of the O₂ content in these tests, the apparatus was purged with N₂ before the test water was introduced. During each test approximately 700 cc of water was exposed to 3.14 square inches of metal. Composite corrosion data of A-285 steel are shown in Table 3 for commercial inhibitor "A" based on sodium nitrite and for activated sodium sulfite in each of two waters containing 8 ppm O₂ and 11 ppm O₂ respectively.

Based upon the data obtained in these tests, it was quite evident that inhibitor A is necessary to reduce corrosion and that this inhibitor is much more efficient than activated sodium sulfite. The reason for accelerated corrosion experienced when excessive (440 ppm) sodium sulfite was used is not known. This dosage represents the equal cost equivalent of 2000 ppm of inhibitor A. It should be pointed out that since inhibitor A is a commercial product composed of a number of ingredients, its effectiveness can be attributed to the fact that corrosion mechanisms other than O₂ attack are being mitigated. Sodium sulfite on the other hand is used exclusively as an oxygen

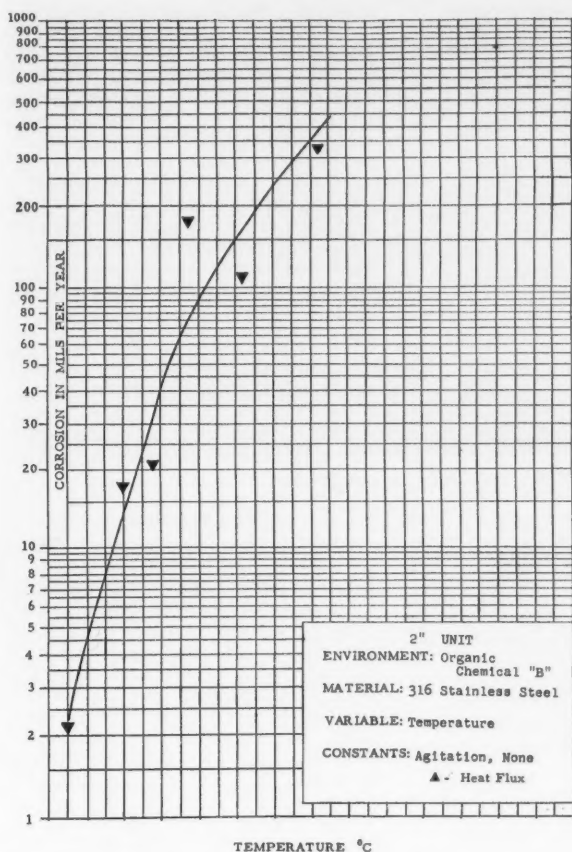


Figure 8—Effect of temperature on corrosion of Type 316 stainless steel in organic chemical "B".

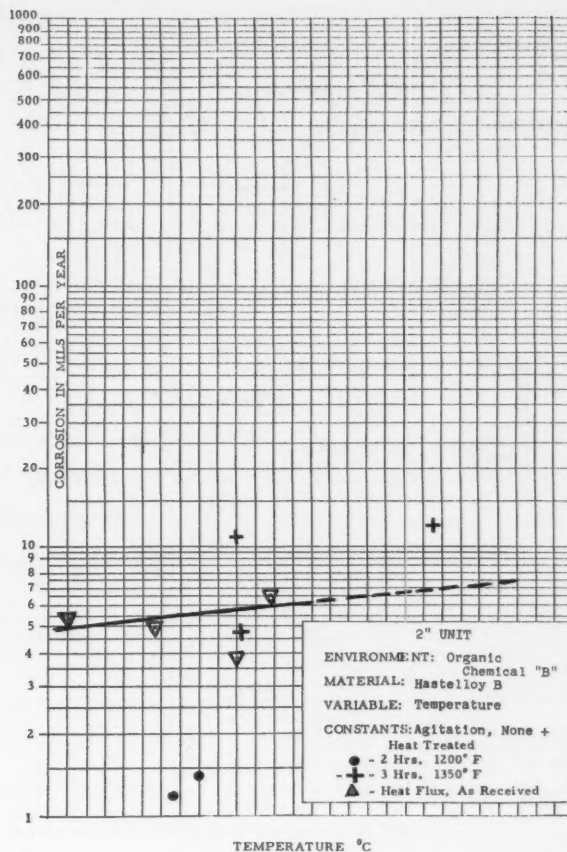


Figure 9—Effect of temperature on corrosion of Hastelloy B in organic chemical "B".

TABLE 4—Vapor-Liquid Corrosion of Various Alloys in 65 Percent HNO₃ Using Pressurized Interface Heat Transfer Unit

Metal	Gauge Press	Heat Flux Immersion		Heat Flux ^E ½ Immersion		Cooling ^E ½ Immersion		Control Immersion		Control Vapor	
		Temp° C	MPY	Temp° C	MPY	Temp° C	MPY	Temp° C	MPY	Temp° C	MPY
321 SS.....	4.5	138	107	140	142	122	21	127	23	126	23
304 SS.....	15.0 ^A	160	3,400	170	3,350	143	569	151	2,370	...	303
309 SS.....	15.0 ^A	162	107	176	106	142	34	149	64	...	25
310 SS.....	8.5	147	33	146	47	126	11	135	14	133	13
Inconel.....	6.0 ^B	152	9,800	153	10,700	126	78	135	18,100	131	1,100
Multimet.....	6.5	142	36	143	42	124	17	129	17	127	23
Haynes Alloy 25.....	15.0	156	149	160	115	132	67	141	72	136	86
Hastelloy Alloy C.....	7.5 ^A	168	4,500	147	2,400	129	863	135	2,600	118	408
Titanium.....	30.0 ^C	201	2	225	2	170	15	181	2	174	1
Zirconium.....	30.0 ^D	171	<1 ^F	179	<1 ^F	142	<1 ^F	155	<1 ^F	147	<1 ^F

NOTES: A—Estimated Pressure; B—18 hour exposure; C—48 hour exposure; D—72 hour exposure; E—Temperature reported is for liquid phase area of specimen, vapor phase temperatures run 2 to 10 C hotter; F—Actually <0.1 MPY.

scavenger and not as an over-all corrosion inhibitor.

Pressurized—Interface Heat Transfer Conditions

One of the most difficult field corrosion problems to simulate in the laboratory concerned condensation of gases under elevated temperature and pressure. In this problem process gases containing unknown concentrations of NO₂, NO, O₂, N₂, and water vapor are cooled and condensed from 550 to 600 F (288 to 315 C) to 135 F (57 C) at 100 psig in a vertical heat exchanger. The plant heat exchanger is composed of 400 1-inch OD

by 16 gauge seamless 321 stainless steel tubes 20 feet long. Process gases are on the tube side with cooling water on the shell side. The condensed material removed from the exchanger outlet analyzes 35 percent HNO₃.

The corrosion pattern of the plant exchanger was confined to the inlet of the tubes 2 to 4 inches from the tube sheet where the hot gases were condensing on the tube walls. Failed tubes were plugged so that the unit could remain in operation. After approximately three years of operation so many tubes had been removed from service that the entire exchanger required retubing. When

304 low carbon stainless steel was used, no improvement in service life was observed. Plant tests on individual 309 stainless steel and 310 stainless steel tubes also showed no improvement. A study of plant operations revealed that removal of a waste heat boiler up-stream prior to plant start-up had actually caused the heat exchanger to handle gases at a considerably higher temperature than originally anticipated. The tube failures were tentatively diagnosed as accelerated corrosion caused by excessive temperatures, since the exchanger was actually functioning as a gas cooler as well as gas condenser. The problem resolved itself

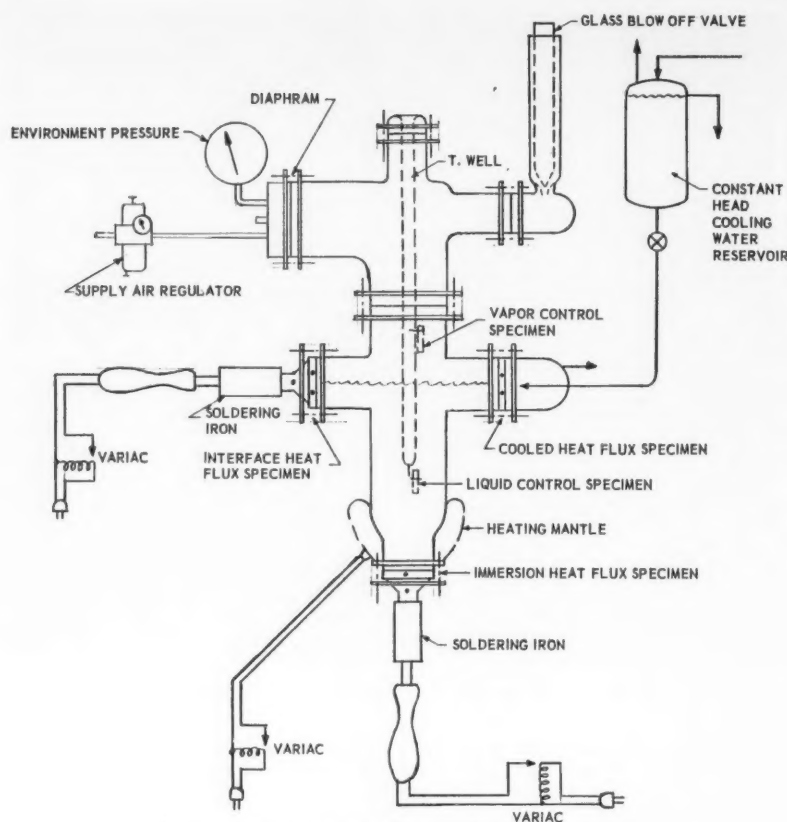


Figure 10—Pressurized interface heat transfer corrosion apparatus.

into the selection of construction materials for this exchanger or for an additional exchanger to be used on either a permanent or expendable basis immediately up-stream of the existing exchanger.

In order to meet the pressure and vapor phase cooling conditions of this plant problem, a new type of laboratory apparatus had to be designed. Because of the very high corrosivity of the nitric acid environment, an all glass unit including let-down valve and pressure measuring device was necessary. Although the selection of glass limited operating pressure to a maximum of 50 psig, the laboratory tests were designed primarily for the purpose of screening materials for eventual plant tests.

The laboratory apparatus designed to meet the above conditions was made from borosilicate glass pipe fittings and included many of the features previously described. A schematic diagram of the unit is shown in Figure 10. It can be seen that in addition to the immersion heat transferring surface, two vertical surfaces have been added. The one on the left is for heating a vapor-liquid interface coupon and the other one on the right for cooling a vapor-liquid interface coupon. A photograph of the unit is shown in Figure 11. It can be seen from Figures 10 and 11 that five different exposure conditions are provided in the pressurized heat transfer unit: 1—heat transfer surface, complete immersion; 2—heat transfer surface, partial immersion; 3—cooling-condensing sur-

face, partial immersion; 4—complete liquid immersion (control) and 5—complete vapor exposure (control).

Heat is supplied to the unit through the two heat transferring specimens and a heating mantle on the lower section of the apparatus. No agitation is provided. Seven temperatures are taken with thermocouples: 1—at the center of the complete immersion specimen; 2 and 3—the vapor and liquid areas of the partially immersed heating specimen; 4 and 5—the vapor and liquid areas of the cooling specimen; and 6 and 7—in the liquid and vapor phase areas of the apparatus. It should be pointed out that the temperature of the vapor phase areas of the interface specimens runs 2 to 10 C hotter than the liquid phase areas which are referred to in Table 4.

In order that the unit might be operated within the 50 psig safety limit a glass pressure relief valve was developed which was based upon the operating principle of a spring loaded valve. In this design a glass cylinder was loaded with a sufficient amount of lead shot to activate at 45 psig. A schematic diagram of the valve is shown in the right side of Figure 12.

A diaphragm-type pressure gauge was purchased so that operating pressures could be observed. This gauge system is shown schematically in the left side of Figure 12. The pressure exerted on the diaphragm (Q) by the environment is opposed by a measured supply of air pressure on the opposite side of the

diaphragm. For successful operation, supply air should be approximately 5 pounds per square inch greater than the system operating pressure. All excess supply air is bled from the housing block through a very small orifice (O). The amount of air thus released is controlled by the position of the diaphragm in relation to the orifice (e.g., an excess of pressure in the air supply pushes the diaphragm (Q) away from the orifice (O) allowing escape of excess supply air which in turn drops the supply air pressure until it equals vessel pressure). Environment pressure is thus transmitted on a 1 to 1 ratio through the diaphragm which oscillates as necessary to regulate air flow (pressure) from the block. The equilibrium pressure is measured on a bourdon gauge. The air pressure can be used to activate controls which in turn will regulate heat flow to the heat transferring specimens.

Test Procedure

After the test coupons were cleaned in acetone, weighed on an analytical balance, and secured in the apparatus, 1100 cc of 65 percent HNO_3 , diluted from 70 percent analytical grade acid, was poured into the equipment. This volume of acid was just sufficient to produce a vapor-liquid interface on both the heating and cooling interface specimens. The top section was then secured and the entire apparatus shielded with a $\frac{3}{8}$ -inch thick protective plastic sheet before electric current was applied. Variac settings on the two heat transfer specimens and the mantle were adjusted to give the desired temperature and pressure readings. All runs were of 24-hour duration unless otherwise noted.

A concentration of 65 percent HNO_3 was selected because actual concentration in the corrosion zone of the plant heat exchanger was unknown, and because it was felt that the NO_2 content in the vapor phase of any nitric acid environment would be more a function of pressure and temperature rather than concentration of the acid in the liquid phase. The selection of this concentration also permitted a comparison of test results with those obtained under boiling atmospheric conditions as defined in ASTM Specification A-262-55T.

To date some 23 runs on 10 alloys have been made in the pressurized heat flux apparatus on 65 percent nitric acid. Tabular results of some typical runs are given in Table 4.

Discussion of Results

None of the laboratory runs could conceivably duplicate plant conditions precisely; first, because of the pressure limitations of the glass equipment and second, because of the unknown composition of the plant condensing gases.

Based on the data obtained in the laboratory, none of the alloys tested except zirconium and possibly titanium A-55 offer satisfactory resistance to 65 percent HNO_3 under elevated temperature and pressure. Even titanium is questionable because of excessive attack, 15 MPY, in the condensing vapor phase.

It was observed in all runs that brown

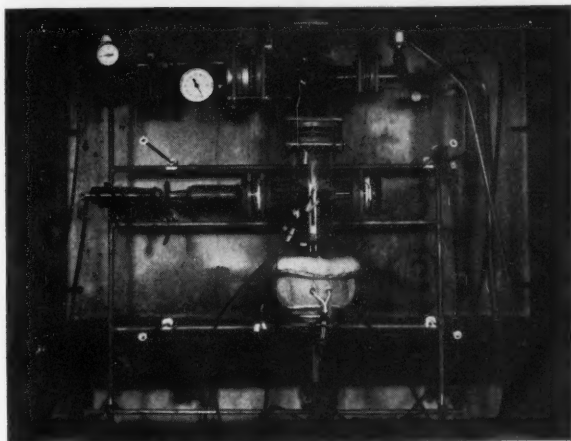


Figure 11—Pressurized interface heat transfer apparatus.

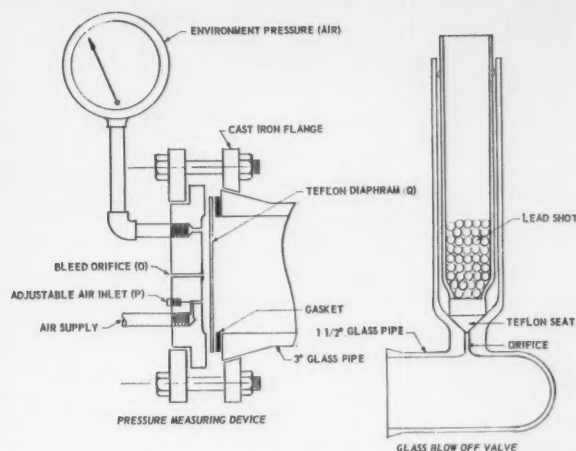


Figure 12—Schematic diagrams of pressure measuring device and gas blow off valve.

NO_2 fumes collected in the vapor areas of the laboratory apparatus and that there was little evidence of actual condensation on the metal specimen suspended in the vapor phase. All condensation took place on the outer walls of the apparatus and on the partially submerged air-cooled specimen. A literature search⁵ revealed that titanium may undergo a pyrophoric reaction in red fuming nitric acid when moisture content is below 1.34 percent in the presence of NO_2 . Although this condition may not exist in the plant, it could conceivably develop on the vapor phase specimen in the laboratory apparatus. For this reason additional testing of titanium was suspended. It should also be noted that pyrophoric reactions of zirconium in nitric acid have also been reported.^{6,7,8}

Conclusions

Data obtained in the laboratory on austenitic stainless steels (AISI 300 Series) indicate that these materials are completely unsuited to nitric acid at elevated temperature and pressure. These findings confirm plant experience with these materials and also agree with various literature references.

It was further concluded that the more highly alloyed materials (Hastelloy alloy C⁽³⁾, Inconel alloy⁽⁴⁾, Haynes alloy 25⁽³⁾, and Multimet⁽³⁾) are similarly unsuited to 65 percent nitric acid under the elevated pressure and temperature used in these tests.

Although titanium A-55 shows adequate resistance in all liquid phase exposures, the excessive corrosion (up to 15 MPY) sustained in the vapor phase interface cooling specimen makes this alloy questionable. Because the vapor

⁽³⁾ The terms, "Haynes," "Multimet," and "Hastelloy" are registered trade-marks of Union Carbide Corporation.

⁽⁴⁾ Registered trade-mark of International Nickel Company, New York.

phase control specimen, suspended in the vapor phase and undergoing no heat transfer, did not show accelerated attack it was concluded that the unsuitability of titanium under specific conditions would not be detected in more conventional corrosion testing techniques. Zirconium was the only metal so far tested which can be recommended for further testing and for possible consideration in the plant.

In addition to the above useful information concerning the suitability of alloys in nitric acid, it was concluded that the pressurized interface heat flux unit had demonstrated its usefulness sufficiently to warrant the purchase of automatic temperature and pressure recorders. These will be incorporated in the remaining runs on nitric acid and for the evaluation of other volatile corrosives, such as hydrochloric acid, formaldehyde and ammonia. Further refinements such as the insertion of electric resistance corrosive measuring device probes will be developed as plant problems dictate.

Acknowledgments

The author wishes to express his appreciation to F. L. Whitney for help in the overall test program and to F. E. Cole for his excellent suggestions and assistance in carrying out the laboratory testing procedures.

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DISCUSSION

Questions by F. W. Fink, Battelle Memorial Institute, Columbus, Ohio:

1. Can you describe the design of the gasket used to provide a seal on the specimens used in the heat transfer experiments?

2. What sort of crevice attack, if any, do you experience?

Replies by A. Orman Fisher:

1. Our research on gasket designs revealed that an all Teflon⁽⁵⁾ Snap-On* gasket with a smooth ground face against the specimen was the most satisfactory. Earlier tests with Teflon envelop gaskets resulted in gradual embrittlement of the filler material because of excessive heat. This resulted in poor seating when the gaskets were re-used. The Teflon "T" gaskets were tried but were found to promote crevice attack under the gasket presumably because of the bead on the gasket facing the specimen. This bead on the specimen side of the gasket could not easily be removed because of the 3 metal clips fastened into the "T" gasket.

2. Crevice corrosion was experienced in the 1-inch diameter unit when the "T" type Teflon gaskets were used as mentioned above. Crevice attack was particularly prevalent in phosphoric and sulfuric acid environments. By employing a 2-inch unit, which gave better heat distribution to the specimen, and using a Teflon Snap-On type gasket with smooth face, no further crevice corrosion was experienced.

⁽⁵⁾ E. I. duPont de Nemours and Co., Inc., Wilmington, Del.

* Belmont Packing Co., Philadelphia, Pa.

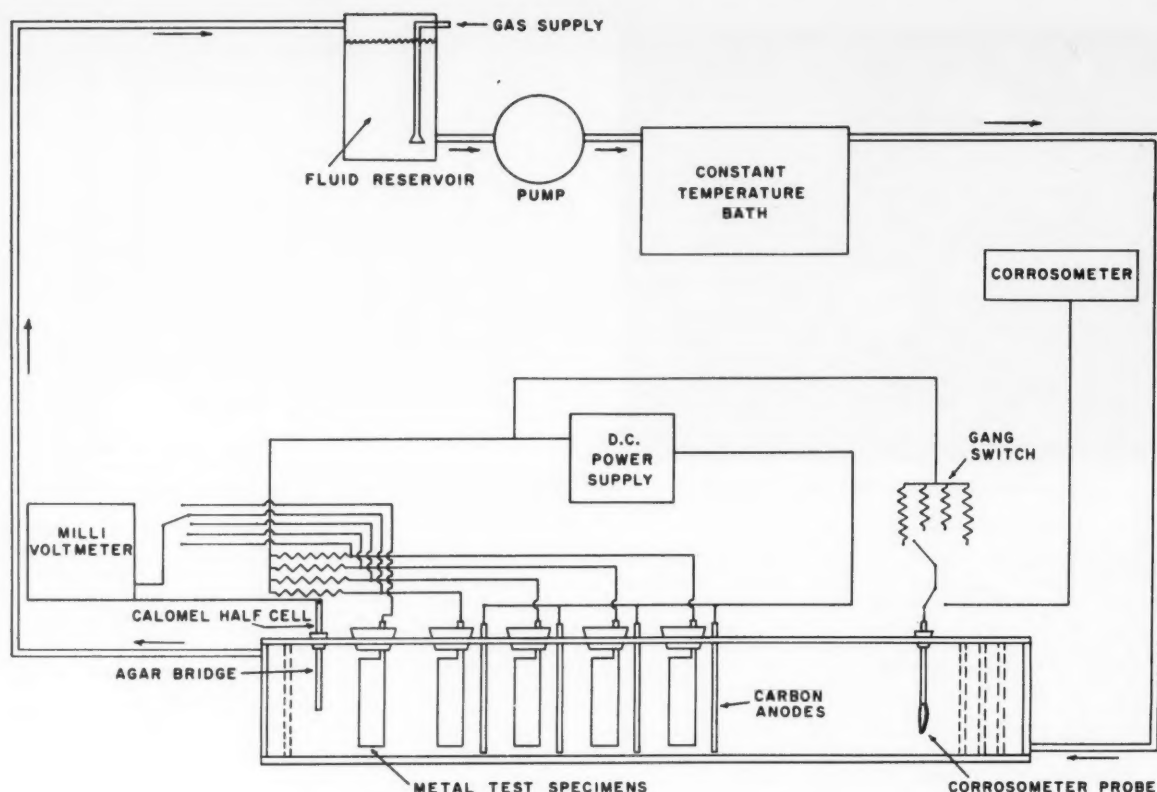


Figure 1—Schematic showing major components of test equipment.

Cathodic Polarization of Steel In Salt Water*

By A. R. ERBEN

Introduction

MOST INSTALLATIONS using cathodic protection as a means of corrosion control, are functioning properly using the accepted criterion of 10 ma/sq. ft. current density or less. There have been instances in the use of cathodic protection where expensive premature corrosion failures were experienced, and where the accepted criteria did not seem to fit the problem. Field measurements indicated that current requirements for complete protection for these exceptions ranged from 7.5 to 10 times the accepted 10 ma/sq. ft. current density. The tests described in this paper were run on the assumption that these high current requirements were dictated by variables that could be controlled and duplicated in the laboratory.

Experimental Procedure

Figure 1 shows the major components

* Submitted for publication July 28, 1960. A paper presented at a meeting of the South Central Region, National Association of Corrosion Engineers, Tulsa, Oklahoma, October 5-7, 1960.

of the equipment. It consisted of: (1) a circulating pump, (2) a fluid reservoir, (3) constant temperature water bath, (4) constant voltage dc current supply, (5) potentiometer, (6) electrical resistance corrosion measuring device, (7) calomel half cell, (8) carbon anodes and (9) the test cell.

The pump used was a Randolph Model 500 using undersized modified polyvinyl chloride tubing instead of the live rubber. This allowed the flow of corrosive media without affecting the pump mechanism. The pump was supplied from a polyethylene reservoir of three liter capacity. From the pump the fluid passed through approximately 20 feet of $\frac{3}{8}$ -inch glass tubing so bent to fit into the thermostatically controlled water bath. The rate of flow was held to about 1.4 liters/minute. By this means a constant temperature was held in the test cell.

The cell was constructed of $\frac{1}{4}$ -inch plastic in the form of a water tight rectangular box. Each end contained baffle

Abstract

A laboratory study was made of the effect on several variables on the cathodic polarization of steel. For several phases of testing, actual produced fluid from West Texas oil fields was used. Laboratory work included studies involving temperature changes, the effect of two corrosive acid gases, the effect of varying amounts of an organic acid, and the comparison of actual produced fluids with synthetic fluids. It was found that changes in temperature from 78 F to 150 F had a decided depolarizing effect on steel in salt water. Mineral constituents of the fluids handled dictated the amount of current needed for the cathodic polarization of steel. The addition of carbon dioxide and hydrogen sulfide definitely depolarized steel in a salt water system.

3.6.8, 5.2.1

plates which served to steady the fluid flow rate in the cell. Fluid entered at the bottom of one end of the cell, passed through three baffle plates, flowed across the steel test specimens, through another baffle plate and out of the top at the opposite end. The top of the cell contained entry ports for introduction of the graphite anodes, reference electrode bridge, corrosion probe, and test specimens. The graphite anodes used were

About the Author



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$\frac{3}{8}$ -inch carbon stock approximately 5 inches long, tapped for a bayonet type plug. The test specimens consisted of 0.015-inch shim stock, 1020 steel, cut-to-size of 1-inch x 3-inch with a $\frac{1}{4}$ -inch x 1-inch mounting stub on top. The stub was inserted through a neoprene stopper fitted into the top of the cell where electrical contact was made.

The test cell contained five specimen entry ports, four of which also included two companion ports for the carbon anodes. This allowed four separate cathodic protection circuits, each independent of the other, and one blank specimen with no applied current. The current was supplied by a constant voltage 220 v power supply. The amount of current supplied to each of the test specimens was controlled by a fixed resistor in each circuit.

The corrosion probe was so wired that protective current could be applied to the metal test strip. The probe was the standard strip type S2 x $\frac{1}{2}$. While current was applied, the probe was disconnected from the electrical resistance corrosion measuring device. At periodic intervals, the current was cut off and a reading taken. The amount of current

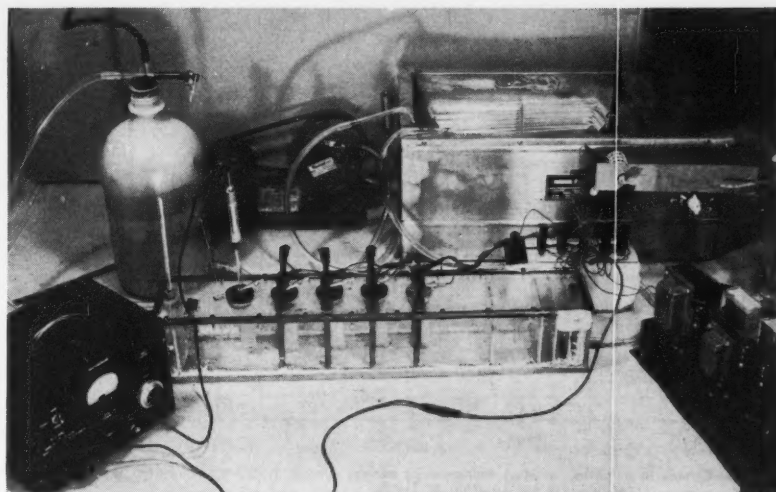


Figure 2—Test equipment in use without the corrosion probe in place.

applied was controlled by a fixed resistor in the return line to the power supply.

The potentials of the steel specimens in the test cell were periodically checked with a calomel half cell and a specially built potentiometer. Contact with the effluent was made through use of an agar bridge inserted near the steel specimen.

Figure 2 shows the test equipment in use without the probe in place.

Constant Current Densities at Varying Temperature (Produced Sour Water)

Figure 3 shows the effect of temperature changes on the potential of mild steel in a sour water with the current density remaining constant. Four current densities were studied: 35 ma/sq ft, 50 ma/sq ft, 75 ma/sq ft and 100 ma/sq ft. The temperature was gradually increased from an initial reading of 100 F to a maximum of 150 F. All the potentials closely approached that of the blank as the maximum temperature of 150 F was reached. A slow reduction to room temperature

(78 F) showed all of the specimens, except the blank, to become more negative again with all but the one with the lowest current density stabilizing at a more negative value than -0.780 v with respect to a calomel reference cell. Figure 4 shows a repeat of this test but this time the starting temperature was 78 F. The results were identical to the first test.

The water used for these two tests was produced fluid with the following mineral analysis:

Sodium	9,765 mg/l
Calcium	1,357 mg/l
Magnesium	414 mg/l
Sulfates	3,482 mg/l
Chlorides	15,495 mg/l
Carbonates	None
Bicarbonates	1,040 mg/l
Total solids	31,553 mg/l
pH	6.80
Sp. gravity	1.0217
Hydrogen sulfide	1200-1400 ppm

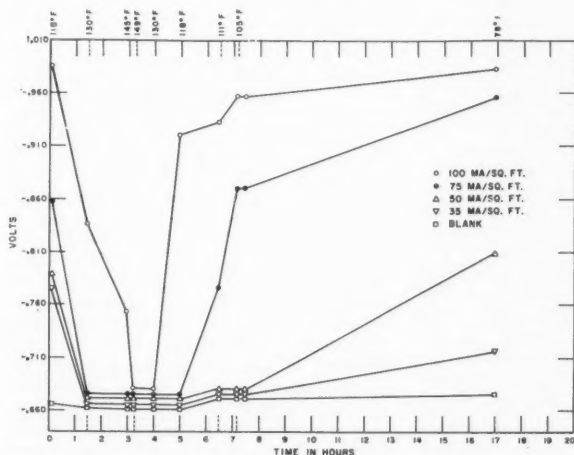


Figure 3—Effect of temperature changes on potential of mild steel in a sour water with the current density remaining constant.

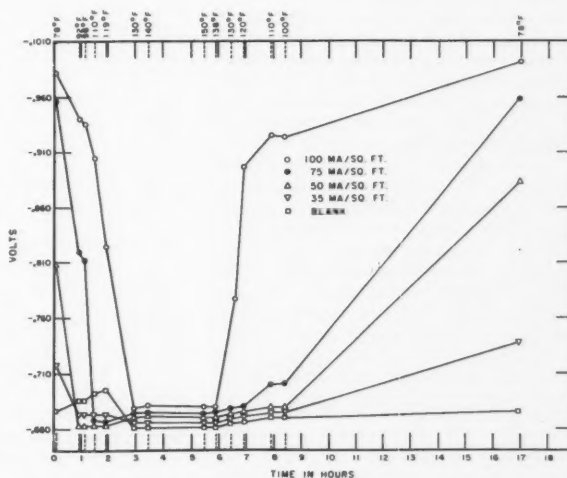


Figure 4—Same as Figure 3 but with starting temperature of 78 F.

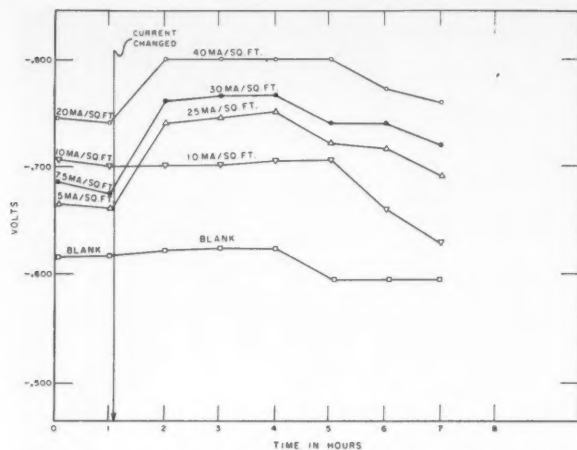


Figure 5—Change in potentials of steel specimens at various current densities. Temperature was constant at 150 F.

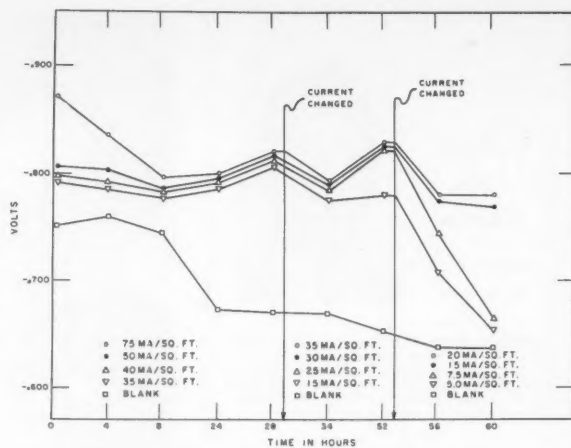


Figure 6—Change in potential with time at various current densities in synthetic sour water. Temperature was constant at 150 F.

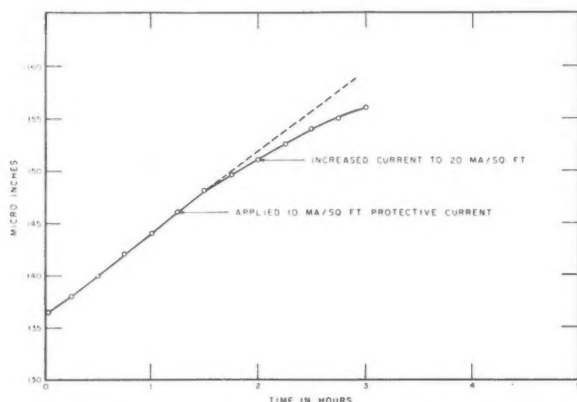


Figure 7—Corrosion rates before and after application of cathodic protection. Temperature was constant at 150 F.

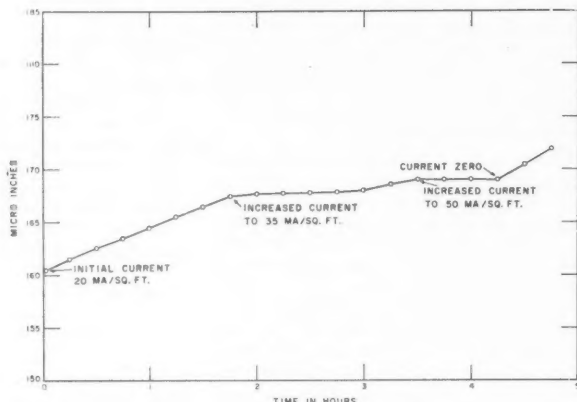


Figure 8—Corrosion rates with varying cathodic protection. Temperature was constant at 150 F.

Varying Current Densities at Constant Temperature

Produced Sour Water

A test was run using current densities of 5, 7.5, 10 and 20 ma/sq ft respectively. Figure 5 shows very little change in the potentials of the steel specimens at these current densities. After about one hour the current densities were increased to 10, 25, 30 and 40 ma/sq ft respectively. Actually the specimen receiving 10 ma/sq ft current density at the onset of the test was left at that same density and the others increased as indicated in Figure 5. There was a shift in the negative direction by the three specimens which had the higher current densities applied. This shift took place over a period of about one hour. After a stable period of about two hours, the potentials again drifted in the positive direction, and after six hours had drifted back to potential values closely approaching those before the current was increased.

Synthetic Sour Water

Figure 6 shows the results of starting with high current densities and gradually

reducing these densities at a constant temperature in synthetic sour water. Current densities of 35, 40, 50 and 75 ma/sq ft were initially applied and the potential allowed to stabilize. After about 30 hours the current was lowered to 15, 20, 30 and 35 ma/sq ft respectively. All of the potentials shifted slightly with the exception of the specimen with 15 ma/sq ft applied current. The latter potentials drifted to about the same potential level they had before the current reduction. After about 23 hours at these current densities the current was reduced again to 5, 7.5, 15 and 20 ma/sq ft respectively. This time the two lower densities slowly approached the potential of the blank after about seven hours. The two higher densities shifted to potentials slightly below -800 v and then stabilized at this point. This shows that prepolarization at high current densities tends to maintain the potential of the steel specimen even though current densities are reduced. It also shows that a very definite amount of current is needed to maintain polarization in this system.

The water used for this series of tests contained the following:

CaCl ₂	10,000 ppm
NaSO ₄	3,500 ppm
NaCl	60,000 ppm
MgCl ₂	5,000 ppm
NaHCO ₃	1,000 ppm
H ₂ S	1,600 ppm

Studies in Produced Sour Water With The Corrosion Probe

While the produced sour water was in the system the blank corrosion rate was measured and the rates determined at the various current densities using the standard S2 x 1/2 corrosion probe. Figure 7 shows this blank rate at 70 MPY and fairly steady. Ten ma/sq ft current density was applied and the rate slowed to 53 MPY. The application of 20 ma/sq ft reduced the corrosion rate to 35 MPY or half that of the blank.

Figure 8 shows a run started with a current density of 20 ma/sq ft and a rate of 35 MPY. By increasing the current density to 35 ma/sq ft the corrosion rate was reduced to zero for about one hour but then it started to increase again. Increasing the current to 50 ma/sq ft

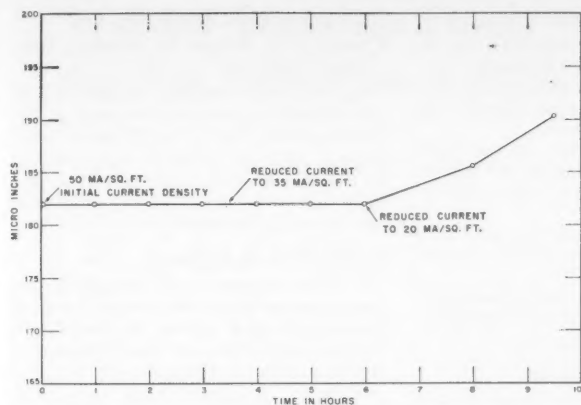


Figure 9—Effect of prepolarization on corrosion rates. Temperature was constant at 150 F.

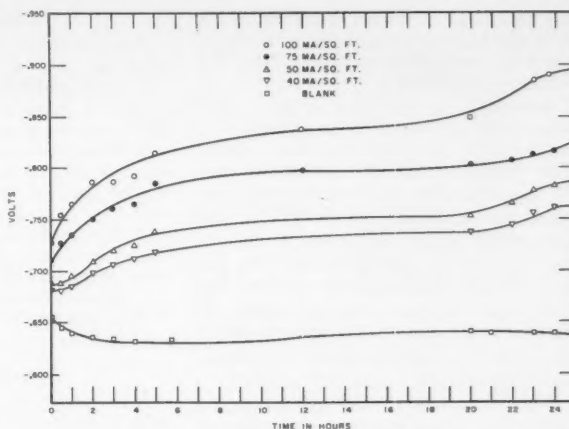


Figure 10—Application of four different current densities in a sweet environment.

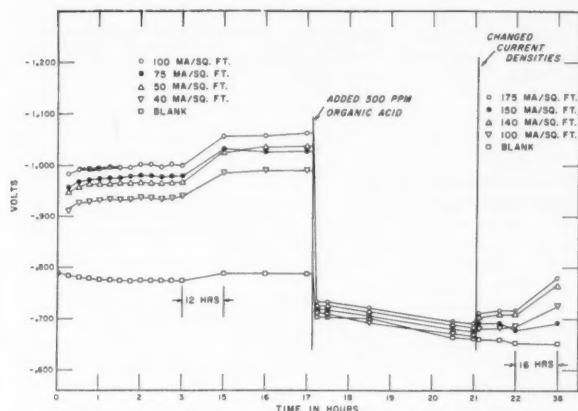


Figure 11—Effect of several variables at various current densities.

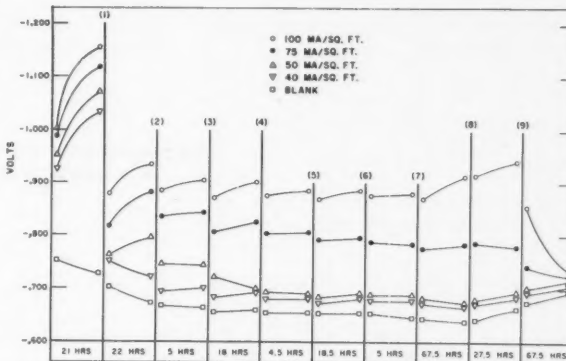


Figure 12—Effect of acid gases and the addition of organic acid in definite increments on potential of steel. Temperature and current were constant.

reduced the corrosion rate to zero and held it there. With removal of the current entirely the rate again established itself at 70 MPY.

To investigate the effect of prepolarization on the probe 50 ma/sq ft current density was applied and the corrosion rate held at zero. Reducing the current level to 35 ma/sq ft still held the corrosion rate at zero (Figure 9). At 20 ma/sq ft the corrosion rate started back up again and after two hours had assumed a rate of 35 MPY.

Constant Current Densities at Constant Temperature

Synthetic Sweet Water

The water used for this test was distilled water which contained 5 percent brine, 500 ppm organic acid and was CO₂ saturated. The CO₂ used was passed over heated copper turnings to remove any traces of oxygen. Figure 10 shows the application of 40, 50, 75 and 100 ma/sq ft current densities. Over a 25 hour period only the specimens with the two highest current densities had reached a potential level of —.780 v or more with reference to a calomel half cell. The author is at a loss to explain the slight

shift in potentials during about the last three hours of the test.

Synthetic Sweet Water-Acid Effect

In order to study the variables involved in the previous tests it was decided to study their effects one at a time. A synthetic system using 5 percent brine in distilled water purged free of oxygen with an inert pure gas was started. The temperature was maintained at 140 F. Current densities of 40, 50, 75 and 100 ma/sq ft were applied to the steel specimens and allowed to stabilize for 17 hours. As Figure 11 shows, all the potentials went more negative than —1.000 v except the specimen with the 40 ma/sq ft current density. Upon the addition of 500 ppm organic acid there was an immediate effect on all the specimens including the blank. All the potentials were shifted in a positive direction and stabilized below —.700 v. After four hours the current levels were increased to 100, 140, 150 and 175 ma/sq ft respectively. There was very little immediate effect and after 17 hours the potentials of the specimens with the two highest current densities had shifted to a potential level more negative than —.780 v.

Synthetic Sweet Water-Acid and Gas Effect

After having observed the pronounced effect of the organic acid on the potential of steel having varying amounts of current applied it was decided to study the effect of acid gases plus the addition of organic acid added in definite increments. To do this a pure system was started again and current in the amounts of 40, 50, 75 and 100 ma/sq ft applied to the metal specimens. A blank with no current applied was also run.

Figure 12 shows all the potentials stabilizing above —1.000 v. The blank stabilized at —.730 v. After 21 hours the fluid was saturated with CO₂ and an immediate effect on the potential was recorded for all the specimens (Point 1). There was an immediate shift in the positive direction. After 22 hours three of the specimens had stabilized at —.800 v or above. One specimen potential along with the blank drifted in the other direction. At Point 2, 100 ppm organic acid was added and an immediate effect on all the specimens again noted. This time only the specimens with the two higher current densities applied retained most of their polarization. The specimens with

the two lower current densities along with the blank remained fairly steady at the level attained immediately after the addition of the acid.

Additions of 100 ppm organic acid were made at Points 3 through 8 where a total of 700 ppm acid had been added. The blank and the two specimens with 40 and 50 ma/sq ft current density applied were relatively unaffected, as was the specimen with 75 ma/sq ft current density applied. The specimen with the highest current density was affected less each time 100 ppm acid was added. In fact, after 600 ppm acid had been added the potential slowly shifted in the negative direction till it reached -0.945 v.

The system was allowed to stabilize for $27\frac{1}{2}$ hours after the last acid addition and at Point 9 the effluent was saturated with hydrogen sulfide gas. Again there was an immediate effect on the two higher potentials and after $67\frac{1}{2}$ hours, all the potentials had stabilized at about the same values. All the specimens seemed to be depolarized.

Conclusions

As a result of the foregoing tests the following conclusions can be made:

1. Changes in temperature from 78 F to 150 F have a decided depolarizing effect on steel in salt water.

2. Mineral constituents of the fluids handled dictate the amount of current needed for the cathodic polarization of steel.

3. The addition of organic acid to a salt water system has a decided depolarizing effect on steel.

4. The addition of corrosive gases such as CO_2 and/or H_2S definitely depolarizes steel in a salt water system.

Acknowledgment

Due credit should be given to two fellow employees who did much of the routine test work herein presented. Harry Wilchester and Ray Wiederhold, both of Sun Oil Company's Southwest Division, obtained many of the test data and helped devise some of the tests. All of the work herein presented was accomplished in Sun Oil Company's Southwest Division Production Laboratory.

DISCUSSION

Questions by Bryant W. Bradley, Pasadena, Calif:

1. Were the corrosion coupons in the test chamber exposed to the same or different current densities at the same time?

2. If adjacent coupons were exposed to different current densities, isn't it possible that stray current effects could exist and influence the results?

Replies by A. R. Erben:

1. Five coupons were exposed in the system at one time. One coupon received no current and served as the blank, whereas the other four were exposed to different current densities.

2. The possibility of stray current effects has been thoroughly explored and it was found that the potential of individual specimens was unaffected by adjacent specimens receiving either higher or lower current densities. If there was any stray current effect, it was so small that detection was impossible with the instruments available for the tests outlined in this paper.

Any discussion of this article not published above will appear in December, 1961 issue.

Technical Papers on Corrosion Welcomed

Authors of technical papers on corrosion are invited to submit them for review without invitation to the Editor of Corrosion. Write for "Guide for the Preparation and Presentation of Papers" sent free on request to prospective authors.

Welded Stainless Steels For Hot Hydrogen Sulfide Service*

By FRANK J. BRUNS

Introduction

IN SINCLAIR'S hydrodesulfurization units, Type 304 stainless steel is extensively used for the hot effluent-feed exchanger tube bundles of the type shown in Figure 1. When many of these units were being designed, alternative stainless steels particularly the stabilized grades, the extra low carbon grades, and the manganese substituted grades were often suggested for use.

To evaluate the corrosion resistance of several commercial grades, four corrosion test spools containing 11 alloys were exposed in the hot effluent stream from a straight run naphtha desulfurization unit. One set of stainless steels was exposed in the as-received solution-annealed condition, the other three sets had a 25 Cr-20 Ni stainless weld bead laid on each coupon and were in different conditions of heat treatment. After exposure for 3840 hours the test racks were removed and the degree of corrosion determined by weight loss and microscopic examination.

In addition to these high temperature tests, samples of seam-welded stainless exchanger tubing were subjected to standard aqueous corrosion tests, and microscopic examination.

Hot Hydrogen Sulfide Test Procedure

Eleven different alloys were tested. The chemical analyses of these is given in Table 1. Specimens were 1/16-inch thick discs 1 1/2-inch in diameter with a 3/8-inch diameter center hole. Total surface area was about 23.8 cm².

Figure 2 shows the type of specimen

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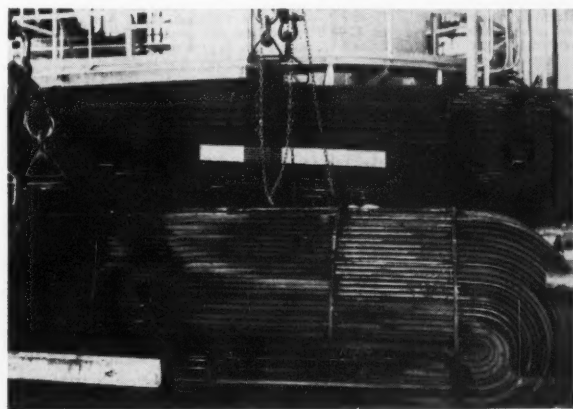


Figure 1—Hydrodesulfurization unit effluent/feed exchanger bundles. This 3/4" U-tube is of Type 304 stainless steel in rear and Type 410 in front. Feed is on shell side.

Abstract

A description is given of the effects of welding, heat-treatment and composition on corrosion rates of various grades of stainless steel exposed to 615 F hydrogen-hydrogen sulfide stream in a commercial desulfurizer. Study was made by weight loss measurements and metallographic examinations. It was concluded that in the thermally stabilized condition, the manganese substituted stainless steels showed slightly better resistance to high temperature hydrogen sulfide than the conventional nickel stainless steels. In the as received, quench annealed condition the former were equivalent to Type 304. It was found also that a thermal stabilizing treatment at 1630 F increased the corrosion rate of all the austenitic stainless steels tested in hot hydrogen sulfide. Seam-welded 304L stainless tubing in the as-welded condition showed no preferential weld zone attack in aqueous media.

3.7.3, 6.2.5, 8.4.3, 4.3.2

used. One set of coupons was exposed to hot hydrogen sulfide in the as-received condition. Before hydrogen sulfide testing, however the three other sets were overlaid with a single weld bead of 25 Cr-20 Ni stainless steel. Weld slag was removed by light sandblasting. One of these sets was exposed in the as-welded condition, the other two were heat treated before exposure. One set was heat-treated at 1200 F in air for one hour, the other heat-treated at 1630 F in air for 16 hours. Heat treating scale was removed by 5 minute immersion in 900 F molten caustic, followed by water quenching. The light brown oxide film produced by this step was then removed by immersion in 140 F inhibited hydrochloric acid. After thorough washing, all specimens were degreased with acetone and the initial weighings made.

All four test racks were exposed in Sinclair's Houston Straight Run Distillate Fuel Hydrodesulfurization Unit in the reactor effluent line at a point ahead

About
the
Author



FRANK J. BRUNS is associated with the Sinclair Research Laboratories, Harvey, Ill. He has a BS in metallurgical engineering from the University of Illinois and a MBA from the University of Chicago. Formerly he was employed by Standard Oil of Indiana.

of the hot exchanger bank. The location is shown in the flow diagram in Figure 3. The feed to this unit is typically a 37 degree API stock containing 0.60 weight percent sulfur. The effluent stream consists of desulfurized product, light hydrocarbon gases, about 50 mol percent hydrogen, and an average 0.45 mol percent hydrogen sulfide. The test specimens were exposed to this stream for 3840 hours at a temperature of 615 F and a pressure of 500 psi.

In Figure 3, the materials of construction used for the various equipment are as follows:

Heater tubes:	5 percent Cr steel
Hot transfer lines:	Colorized 1 1/4 percent Cr steel
Two hottest exchangers:	Tubes: 18-8 (304) Shell: 410 clad C-Mo steel
Three cooler exchangers:	Tubes: 410 Shell: Carbon steel
Reactors:	Shell: 304 Clad C-Mo steel Internals: Colorized 1 1/4 percent Cr steel, 304.

As a result of exposure the specimens acquired a thin adherent sulfide scale which required a 10 minute immersion in 900 F molten caustic, a water quench and subsequent clean-up in inhibited hydrochloric acid for complete removal.



Figure 2—Typical corrosion coupons.

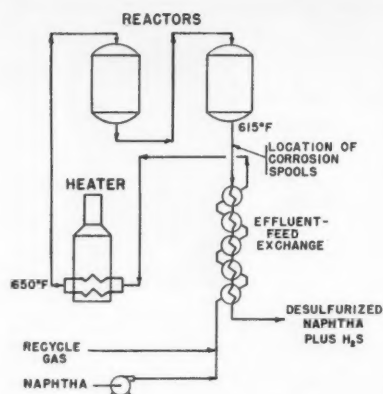


Figure 3—Flow diagram showing high temperature section of naphtha desulfurization unit.

It was realized that this cleaning procedure itself would produce some weight loss in the specimens. Accordingly, duplicate specimens of the same stainless steels, with the same heat treatments were also cleaned by this process and the weight loss determined. Generally the weight loss due to cleaning was less than 5 percent of the corrosion loss for nine of the eleven alloys tested. Type 202 was higher and ranged up to 10 percent while Tenelon after the 1630 F treatment showed a cleaning attack equivalent to about 17.5 percent of the corrosion loss.

Conservatively, all corrosion rates were corrected for cleaning losses although the presence of sulfide scale undoubtedly reduces the attack of the base metal during cleaning. This change in indicated corrosion rate did not affect the relative ranking of the various alloys.

H₂S Corrosion Rates

The corrected corrosion rates are given in Table 2 and are plotted as a bar graph on a semi-log scale in Figure 4. The relative ranking is based on the maximum corrosion rate displayed by the individual alloy type. It is seen that the manganese-substituted grades of stainless steels as a group show the lowest maximum corrosion rates. The second group comprises Types 304L, 347 and 304. Although the Type 430 steel coupon contained only 15.4 percent chromium it had equivalent resistance to 316, 316L and 321 which had higher chromium content. Type 410 lowest in chromium

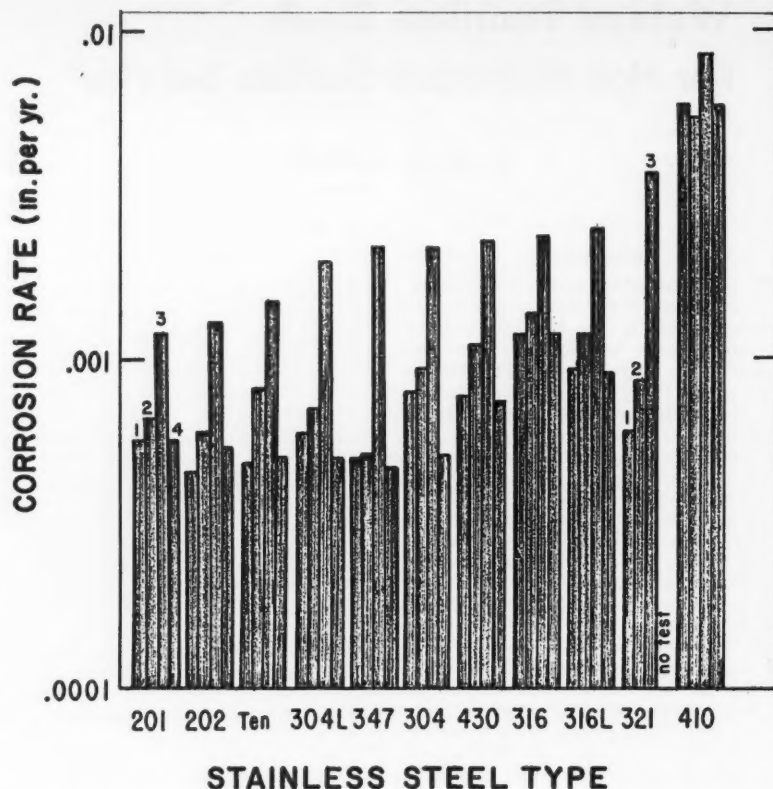


Figure 4—Corrosion rates in 0.45 vol percent hydrogen sulfide at 615 F of stainless steel with various heat treatments. Keys to numbers is as follows: Bar No. 1—As welded, as received; Bar No. 2—Welded, heated 1200 F; Bar No. 3—Welded, heated 1630 F; Bar No. 4—No weld, as received.

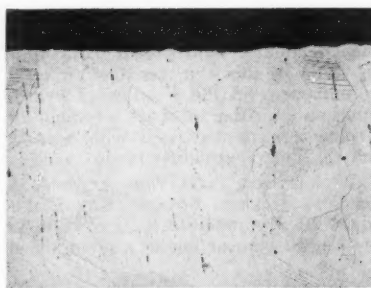


Figure 5—Type 304 stainless steel, as-received, non heat-treated structure. Corrosion rate: 0.00051 IPY. Oxalic acid etch, approximately 200X.

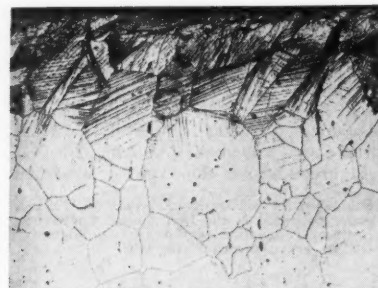


Figure 6—Type 304 stainless steel, heated 1 hour at 1200 F. Corrosion rate was 0.00094 IPY. Oxalic acid etch, approximately 200X.

TABLE 1—Chemical Composition of Stainless Steels Tested

	Element, Percent									Others
	C	Mn	P	S	Si	Cr	Ni	Mo	Cu	
201.....	0.15	6.65	0.016	0.01	0.44	16.4	4.59	.....	.....	.....
202.....	0.13	8.11	0.022	0.01	0.44	16.6	5.21	.....	.....	.....
Tenelon.....	0.11	14.2	0.017	0.01	0.66	15.8	0.28	.....	.....	.....
304L.....	0.015	1.32	0.024	0.010	0.46	18.44	9.70	.....	.....	.....
347.....	0.08	1.61	0.020	0.05	0.52	18.90	11.00	.....	.....	1.18 (Cb)
304.....	0.07	1.00	0.030	0.02	0.25	19.23	8.75	0.57	.....	.....
430.....	0.18	0.46	0.014	0.02	0.63	15.4	.....	.....	.....	.....
316.....	0.05	1.82	0.013	0.01	0.33	18.60	10.70	2.6	.....	.....
316L.....	0.021	1.15	0.022	0.012	0.50	17.16	12.77	2.38	.....	.....
321.....	0.048	1.74	0.013	0.018	0.47	17.46	10.71	0.16	0.22	0.53 (Ti)
410.....	0.12	0.49	0.015	0.016	0.44	13.28	0.12	0.27	.....	.....



Figure 7—Type 304 stainless steel specimen heated 1630 F for 16 hours. Corrosion rate: 0.0022 IPY. Oxalic acid etch, approximately 200X.

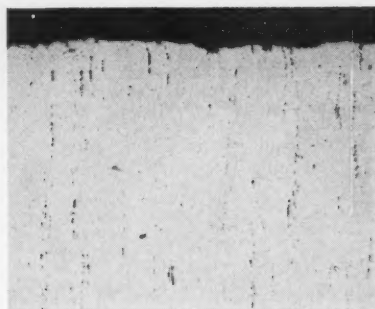


Figure 8—Type 347 stainless steel specimen heated 1 hour at 1200 F. Corrosion rate: 0.00051 IPY. Approximately 200X.

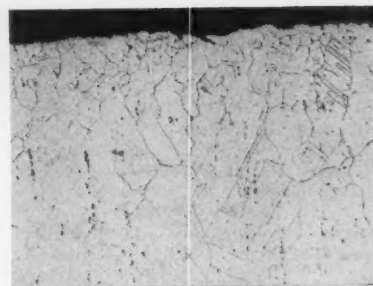


Figure 9—Type 347 stainless steel specimen heated 16 hours at 1630 F. Corrosion rate: 0.0022 IPY. Approximately 200X.

had the lowest resistance to hydrogen sulfide corrosion.

Depositing a weld bead causes recrystallization of the base metal, and carbide precipitation at the grain boundaries of the unstabilized austenitic stainless steels of both the Cr-Ni and Cr-Mn types. By comparing bar No. 1 with bar No. 4 in Figure 4 for each alloy, however, it can be seen that deposition of the 25 Cr-20 Ni weld bead did not increase the overall corrosion rate of the coupon appreciably. In the stabilized or low carbon stainless grades the effects of carbide precipitation are minimized, and in the manganese grades, the presence of manganese may improve the hydrogen sulfide resistance of the chromium-depleted base metal.

It is well known that unstabilized, austenitic stainless steels in the as-welded condition are susceptible to intergranular corrosion by certain aqueous media. However, in these tests the corrosion by hot hydrogen sulfide was a surface reaction, as microscopic examination of all the as-welded specimens revealed no preferential sub-surface attack.

Because the heat of welding affects only a small region adjacent to the weld deposit, the overall effect on the corrosion rate was slight. To obtain a true measure of the change in corrosion resistance caused by carbide precipitation such as produced by welding, the specimens were heated for 1 hour at 1200 F. This caused general carbide precipitation at grain boundaries and on slip planes in

all of the unstabilized, medium carbon austenitic stainless steels, (i.e., 201, 202, Tenelon, 304 and 316). The effect of this heat treatment on the microstructure is shown by comparing Figures 5 and 6 which show the structure of the Type 304 stainless specimens.

The corrosion rate data (Figure 4) indicate that only a small increase in corrosion is produced by this treatment. Thus it is concluded that welding stainless steels does not seriously injure their hot hydrogen sulfide corrosion resistance. Welding of non-stabilized stainless steels however does increase their susceptibility to certain aqueous media which have led to failures in desulfurizer services.

Heat treatment at temperatures around 1600-1650 F is sometimes used to produce discrete carbide precipitation, with homogeneous chromium diffusion instead of continuous networks of carbide precipitation on the slip planes and at the grain boundaries. This "thermal stabilization" treatment makes the steel resistant to intergranular corrosion in aqueous environments, and has been recommended by Dravnieks and Samans¹ to prevent stress corrosion cracking of stainless steels by polythionic acids in commercial units during shutdowns.

To evaluate the effect of "thermal stabilization" on hydrogen sulfide corrosion, one set of specimens in the present tests were, before exposure, heat-treated at 1630 F for 16 hours, to effect thorough homogenization. The micro-

structure produced by this heat treatment varied somewhat with the type of steel.

It was found however that the hot hydrogen sulfide corrosion rate was increased markedly by this heat treatment as is shown by the third bar in the groups of Figure 4. In all of the austenitic steels (and somewhat inexplicably also in the 16 percent Cr Type 430 steel) the hydrogen sulfide corrosion rate of the alloy is increased by this heat treatment. The greatest increase occurred for the two stabilized steels, Types 347 and 321 and for the low carbon 304-L. Backensto² reported a similar increase in the corrosion rate of Type 304-L due to a thermal stabilization treatment, but a decrease for Types 304, 347 and 310.

The results in the present tests are paralleled by the weight changes produced by the cleaning technique, for it was also found that the austenitic steels heat treated at 1630 F lost significantly more weight in cleaning than those heat treated at 1200 F or in the as received condition. It appears that the 1630 F heat treatment produces a more active surface than does the 1200 F treatment.

A comparison of microstructures

TABLE 3—Microstructures of Heat-Treated Stainless Steels Used in H₂S Corrosion Test*

Stainless Steel Type	Heated 1200F-1 Hr.	Heated 1630F-16 Hrs.
201 202	Intergranular carbide precipitation network	Twinned hexagonal grains. No precipitated carbides, slow etching.
Tenelon	Discrete carbides at grain boundaries	Same as 201, 202
304	Heavy carbide precipitation at grain boundaries and slip planes (Figure 6).	Fine carbides within grains (Figure 7).
316	Intergranular carbide precipitation	Larger grain size, intergranular carbide precipitation
304L	Light intergranular precipitation	Very large grains, intergranular precipitation
347	Discrete carbides in grain boundaries and in grains, stringered inclusion colonies (Figure 8).	Larger grains. Intergranular etching (Figure 9).
321	Fine grained, slow etching no carbide precipitation (Figure 10).	Very large grains, discrete carbides at grain boundaries and in grains near surface (Figure 11).

* Oxalic Acid Electrolytic Etch.

TABLE 2—Effect of Welding and Heat Treatment on Corrosion Rate of Stainless Steels

Alloy	Corrosion Rate, In. per Year			
	Welded, As Received	Welded, Heated 1200° F, 1 hr.	Welded, Heated 1630° F, 16 hrs.	No Weld As Received
201.....	0.0006	0.0007	0.0012	0.0006
202.....	0.0004	0.0006	0.0013	0.0005
Tenelon.....	0.0005	0.0008	0.0015	0.0005
304L.....	0.0006	0.0007	0.0020	0.0005
347.....	0.0005	0.0005	0.0022	0.0005
304.....	0.0008	0.0009	0.0022	0.0005
430.....	0.0008	0.0011	0.0023	0.0007
316.....	0.0012	0.0014	0.0024	0.0012
316L.....	0.0009	0.0012	0.0025	0.0009
321.....	0.0006	0.0009	0.0037	0.0009
410.....	0.0061	0.0055	0.0086	0.0060

Commercial Exposure Conditions:

Temperature, Degrees F..... 615
Hydrogen Pressure, psig..... 250
H₂S Concentration, Vol. Percent..... 0.45
Hours exposed..... 3840

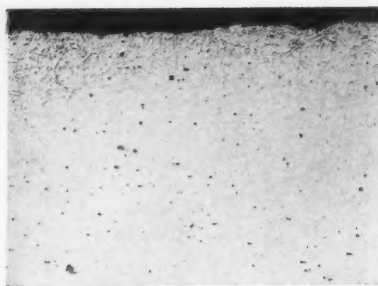


Figure 10—Type 321 stainless steel specimen 1 hour at 1200 F. Corrosion rate: 0.00086 IPY. Approximately 200X.

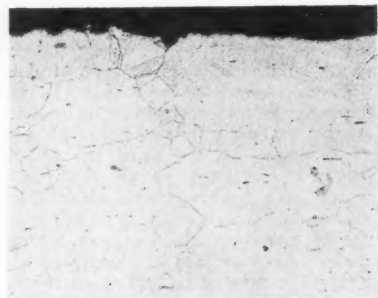


Figure 11—Type 321 stainless steel specimen heated 16 hours at 1630 F. Corrosion rate: 0.0037 IPY. Approximately 200X.

produced by the two heat treatments revealed differences but no clear explanation for the difference in corrosion rates. Table 3 lists the microstructures which were observed. It is noted that the manganese grades show intergranular precipitation as a result of the 1200 F treatment, but are solution annealed at 1630 F. Type 304 shows similar response and all four of these steels are not affected as much by the 1630 F treatment. Figure 7 shows the 1630 F structure of 304.

The steels which are injured most by the 1630 F heat treatment are Types 304L, 347, 316L and 321. These four show no appreciable intergranular precipitation as a result of the 1200 F heat treatment, but do show intergranular precipitation and a significant increase in grain size due to the 1630 F treatment. Figures 8-11 illustrate this. Corrosion of Type 410 is unaffected by heat treatment,



Figure 12—Type 304 stainless steel, 3/4-inch-40 welded pipe. Sample was welded and annealed but not cold drawn. Subsurface corrosion of weld occurred in boiling 65 wt percent nitric acid. Approximately 200X.

but in 430 the 1630 F treatment produces a mixed structure of martensite and ferrite and corrosion is increased.

Fortunately, under the conditions of exposure used the increase in corrosion rate brought about by the 1630 F treatment still only results in a maximum of 0.0037 ipy corrosion rate for the austenitic stainless steels. For more severe conditions heat treatment would have a more important practical effect and the causative factors would require further study.

Welded Exchanger Tubing Tests

Partially as a result of these investigations serious consideration has been given to the use of seam welded stainless steel tube for hot exchangers. Samples of commercially available tubing and pipe have been tested. Both tube and pipe samples tested were electric resistance welded, with no filler metal added. Specimens of Type 304 and 304L were tested. The manganese stainless steels although promising are not readily available as exchanger tube. The material was evaluated by microscopic examination of the welds after various boiling aqueous corrosion tests, namely the 65 percent nitric acid (Huey test), 6 percent copper sulfate (Strauss test) and 42 percent magnesium chloride. Specimens were also immersed in Wackender's solution (6 percent H_2SO_4 through which hydrogen sulfate was bubbled at room temperature) to determine whether stress-corrosion due to polythionic acids would result. Of prime importance was whether the weld zone was more susceptible to corrosion than the parent metal in

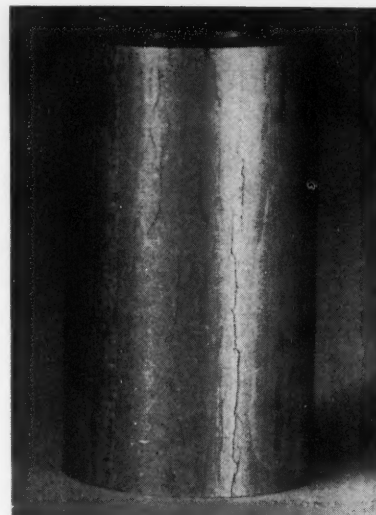


Figure 13—Type 304L tubing (3/4-inch OD x 16 gauge, as welded) stress corrosion cracked by boiling 42 percent $MgCl_2$. Approximately 2X.

aqueous media, since the high temperature hydrogen sulfide tests (above) revealed no appreciable loss in corrosion resistance due to welding.

The results of these tests are given in Table 4. In the nitric acid test sub-surface corrosion was observed in one case (in the Type 304, 3/4-inch Sch. 40 pipe which had been welded, then annealed). This suffered sub-surface intergranular attack of the delta ferrite structure in the center of the weld as shown in Figure 12. This behavior casts some shadow on the serviceability of the welded and annealed 304 for uses where aqueous corrosion is a factor. The other 304 tube which had been cold drawn following welding (producing a 50 percent reduction in cross-section area), had a recrystallized weld structure due to subsequent annealing and did not show sub-surface attack in the Huey test. Neither did the 304L samples even though they contained delta ferrite in the weld structure.

The boiling copper sulfate (Strauss) test did not produce any intergranular attack in any of the samples tested because none, including the as-welded 304L tubing had an intergranular carbide network.

TABLE 4—Results of Corrosion Tests of Stainless Seam-Welded Tubulars

Type	Size	Manufacturing Treatment	Element, Percent								Corrosion Test Results			
			C	Mn	P	S	Si	Cr	Ni	Cu	65 Wt. % HNO_3	6% $CuSO_4$	42% $MgCl_2$	Wackender Sol'n.
304.....	1" OD-16 Gauge	Cold drawn, then bright annealed	0.055	1.38	0.016	0.012	0.49	18.71	8.80	0.11	OK-no weld attack	OK	Stress Cracked	OK
304.....	3/4"-Schedule 40		0.044	1.68	0.020	0.014	0.57	18.67	8.94	0.17	Sub-surface atk. of weld (Figure 12)	OK	Stress cracked	Light weld etching
304L...	1" OD-16 Gauge	Annealed, not cold drawn	0.028	1.03	0.16	0.018	0.38	18.82	10.43	0.08	OK	OK	Many stress cracks 1 short crack	OK
304L...	3/4"-Schedule 40	Annealed, not cold drawn	0.024	1.47	0.018	0.017	0.46	18.46	10.41	....	OK	OK	Many stress cracks	OK
304L...	3/4" OD-16 Gauge	As welded, not annealed	0.030	1.25	0.018	0.008	0.38	18.74	10.69	....	OK	OK	Many stress cracks (Figure 13)	OK

In the boiling 42 percent magnesium chloride, all showed stress-corrosion cracks in less than 24 hours, similar to that of Figure 13 which is the 304L $\frac{3}{4}$ -inch OD-16 gauge tubing. This is a particularly severe test and the light residual stresses in the annealed tubes introduced by mill straightening are enough to cause cracking. As welded the stresses due to forming the strip as tube are much higher and stress cracking in MgCl_2 is to be expected.

Dravnieks and Samans¹ showed that Wackenroder's solution causes cracking in stressed sensitized 304 stainless. Immersion of both the 304 and 304L seam-welded tube samples in this solution for 18 hours did not cause any cracking as determined by microscopic and visual examination. The delta ferrite in the 304 $\frac{3}{4}$ -inch schedule 40 pipe was lightly etched, but the others were unattacked.

Cracking was not expected because the stresses are low (in the annealed tubes) and no intergranular sensitization existed in any of the tubes.

The as welded 304L tubing costs less than the 304 welded and annealed tubing, which in turn is less than the 304 welded, cold drawn and annealed material.

Conclusions

1. In the thermally stabilized condition the manganese substituted stainless steels show slightly better resistance to high temperature hydrogen sulfide than the conventional nickel stainless steels, and in the as received, quench annealed condition they are equivalent to Type 304.

2. A thermal stabilizing treatment at 1630 F increased the corrosion rate of

all of the austenitic stainless steels tested in the hot hydrogen sulfide exposure.

3. Seam-welded 304L stainless tubing in the as-welded condition shows no preferential weld zone attack in aqueous media, and is an economical choice for refinery exchangers in corrosive service, except where chlorides are encountered.

Acknowledgment

R. L. Hildebrand, Sinclair Refining Co., arranged the refinery corrosion testing and A. A. Latko, of Sinclair Research Laboratories, Inc., carried out much of the laboratory work.

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1. A. Dravnieks, C. H. Samans. Corrosion Control in Ultraforming. *API Proceedings*, Division of Refining (1957) May 13.
2. E. B. Backensto, R. E. Drew, J. E. Prior, J. W. Sjöberg. High Temperature Hydrogen Sulfide Corrosion of Stainless Steels. *Corrosion*, 14, No. 1, 27t-31t (1958) Jan.

Any discussion of this article not published above
will appear in December, 1961 issue.

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Development of a Mineral Scale Inhibitor*

By L. W. JONES

Introduction

MINERAL SCALES found in oil production equipment usually can be classified either as "carbonate" or "gyp." The former dissolves in acid with effervescence, while the latter has low acid solubility because it is mainly calcium sulfate. Some of the operational difficulties caused by these scale deposits are: (1) obstruction of fluid flow, (2) impedance of heat transfer, (3) wear of metal parts, and (4) localization of corrosion attack.¹ Several investigators have studied factors influencing scale deposition.^{2, 3, 4, 5}

The expense attributable to scaling in oil producing operations totals many millions of dollars annually. For example, it is estimated that 3,000 heater treaters in this country are continuously impaired by scale. Typical maintenance costs for these treaters are in the range of \$600 to \$1,000 per year. Thus, probably 1.5 to 2.0 million dollars are spent each year to clean and repair this one item. Occasionally a complete heater treater and considerable oil are destroyed by a fire resulting from metal failure at hot spots under scale deposits. To give an idea of the scaling potential of oil field brines, an instance may be cited where 7 cubic yards of scale were deposited in a heater treater from 59,602 barrels of water.⁶ Such brines are normally not recirculated and oil producing equipment may be classed as "once through" systems.

While it is widely known that deposition of calcium carbonate can be inhibited with polyphosphates, field experience has shown that these additives are not entirely satisfactory for controlling calcium sulfate. When used alone, the sodium polyphosphates often fail to prevent scaling in heater treaters and similar equipment due to rapid reversion to the orthophosphate form. Phosphates are often combined with other chelating or sequestering agents and organic materials for use as scale inhibitors. In order to evaluate the basic ingredients and combinations, and to develop more effective agents, a laboratory test program was instituted. Results of this study provided the data given in this paper.

Procedure

Apparatus

The major environmental parameters considered in the design of a laboratory scale testing apparatus were temperature and fluid flow past a metal surface. Deposition of scale on heated metal was desirable to simulate surfaces that receive scale in the field. Simple precipitation of scale solids in glass vessels, as often done

Abstract

The expense attributable to scaling in oil producing operations totals many millions of dollars annually. Causes of precipitation and deposition are fairly well understood but better methods of control are needed. In order to evaluate chemical scale inhibitor components, a laboratory testing device was designed. Performance of sequestrants, surface active agents, colloids, and mixed compounds in the laboratory tester are discussed. Polyphosphates and sodium carboxymethyl cellulose proved effective for calcium carbonate scale and calcium sulfate scale, respectively. Results of tests made over a period of several years led to the development of an inhibitor composition that is capable of inhibiting both carbonate and sulfate scales. The inhibitor is now in field use. 5.8.2, 3.2.3, 8.4.3



About the Author

LOYD W. JONES is a Senior Research Chemist with Pan American Petroleum Corporation, Tulsa, Oklahoma, where he has been employed for 16 years. Most of his work has been research and development relating to oil production problems. He holds patents on a number of chemical corrosion inhibitors and has published several papers on this subject. He has been a member of NACE since 1951.

in laboratory work, may not yield information on adherence tendencies and may not show effects of agents which act as dispersants.

The apparatus that was developed for this study deposits scale on heated metal rotors that turn in water solutions of the scale-forming minerals. A drawing of the apparatus is shown in Figure 1. An important feature is that the heated metal rotors can be easily removed for weighing and cleaning. The rotors are made of short lengths of 3/8-inch tubing with discs of perforated sheet metal welded across the ends. Brass is the usual material of construction. Cylindrical electric heaters (100 watt) are mounted in the shafts and fit inside the rotor tubes which are slip-fitted onto the shafts. A chain and pulley arrangement drives the rotor shafts from the variable speed motor. Rotational velocity is usually equivalent to 10 feet per minute at the rotor edges.

Figure 2 is a schematic drawing of the electrical circuit and shaft assembly. Current for the heaters is provided by bus bars connecting through carbon brushes

which contact slip rings on the rotating shafts. Line voltage is controlled by a variable transformer, and small rheostats are mounted in series with each heater for individual control.

In preparation for a test, the rotors are cleaned, weighed on the analytical balance and mounted on the shafts. Beakers containing the scaling solutions are placed in position to submerge the rotors and are supported by wooden blocks. Reinforced plastic covers are provided to fit the beakers, which are the 400 ml Borosilicate type with the top lip cut off. In the covers are holes through which ther-

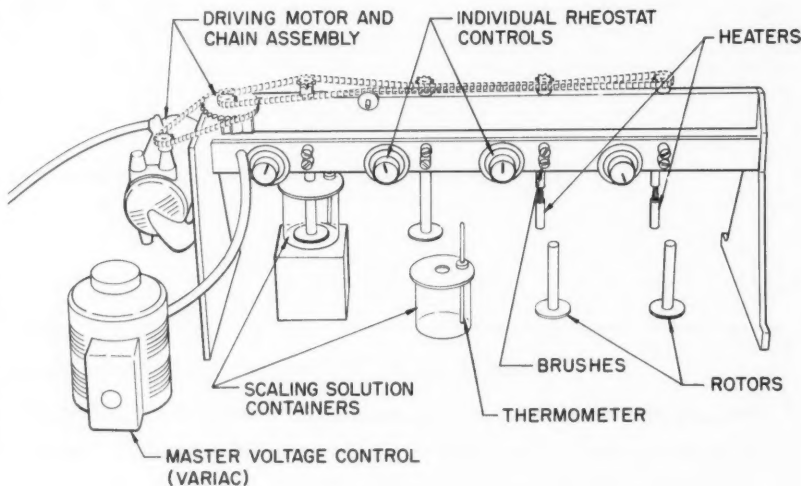


Figure 1—Laboratory testing apparatus.

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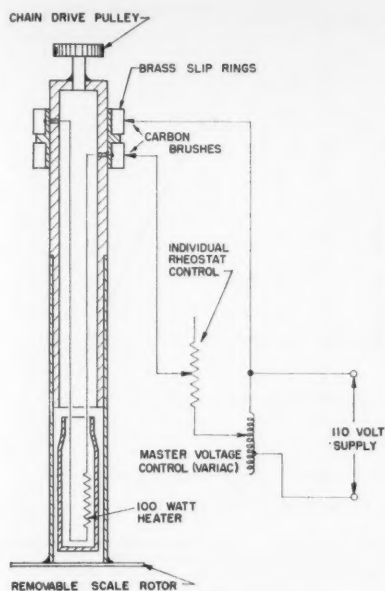


Figure 2—Schematic of electrical circuit and shaft assembly.

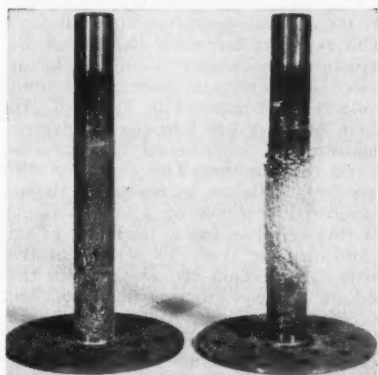


Figure 3—Calcium sulfate scale deposited on test rotors. Right: untreated control; left: deposition partially inhibited.

mometers are mounted in rubber stopper supports.

Scaling Solutions

For the deposition of calcium carbonate, the solution is prepared by dissolving calcium carbonate in water saturated with carbon dioxide at atmospheric pressure and room temperature and containing usually 5 weight percent of sodium chloride. An excess of calcium carbonate is added to the brine to assure saturation. The mixture is stirred several hours with carbon dioxide being constantly bubbled through it. When saturation is reached, the excess calcium carbonate is allowed to settle out and the solution is stored under carbon dioxide. The final calcium content is determined by chemical analysis.

Calcium sulfate scaling solutions are prepared by reacting calcium chloride and sodium sulfate in stoichiometric proportions to yield the desired concentration of calcium sulfate. Extra sodium chloride is added (to that resulting from

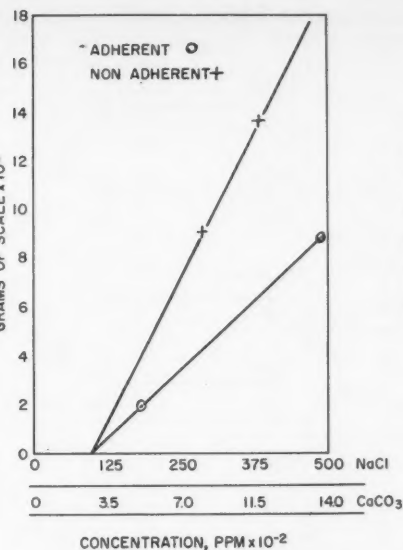


Figure 4—Distribution of scale precipitated from 250 ml of CaCO_3 solution heated to 190 F for two hours.

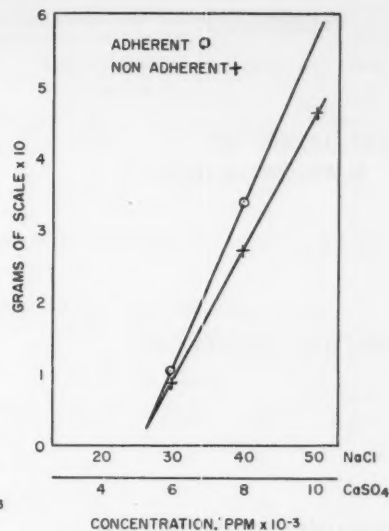


Figure 5—Distribution of scale precipitated from 250 ml of CaSO_4 solution heated to 165 F for two hours.

the reaction of the other salts) to yield a desired concentration, usually 5 percent. Stock solutions are made by separately dissolving the calcium chloride and the sodium sulfate plus sodium chloride. Equal volumes of the two stock solutions are mixed just prior to making the tests.

Operation

Into each beaker are placed 250 milliliters of carbonate scaling solution or 125 milliliters each of the calcium sulfate stock solutions. Additions of scale inhibiting compounds are made to two beakers, and two are left untreated to serve as controls. Rotor motion is started and heat is applied at full line current until the desired temperature is reached. In the carbonate tests, the solutions are heated to 185-190 F for two to three hours. Calcium sulfate tests are run at 165 F for two to three hours. Tests of longer duration have been made for study of inhibitor stability, but this is usually not required.

Total scale precipitated is calculated from the difference in calcium content of the solutions before and after test. The amount of scale adhering to the rotors is determined by direct weighing after the rotors are gently flushed with distilled water and dried. Figure 3 shows the appearance of scale on the rotors. Percentage inhibition of total and adherent scale is calculated from differences between the treated and untreated tests.

Many of the compounds tested were found to be incapable of preventing precipitation of calcium as the sulfate, although calcium sequestration was very pronounced in the carbonate tests. Consequently, only the percentage inhibition of adherent scale is reported for the calcium sulfate tests.

Examples of inhibition calculations for typical tests are given below:

Calcium Carbonate Test

1. The scaling solution contains 50,000 parts per million NaCl and 1,340 parts per million of CaCO_3 . Therefore, each 250 ml portion contains 0.335 grams of CaCO_3 .

2. Average weight of adherent scale on untreated control rotors = 0.0887 grams.

3. Average concentration of CaCO_3 remaining in solution in controls after test = 0.0700 grams (by analysis).

4. Total scale precipitated in controls = $0.3350 - 0.0700 = 0.2650$ grams.

5. Weight of non-adherent scale in controls = $0.2650 - 0.0887 = 0.1763$ grams.

6. Average weight of adherent scale on rotors in treated tests = 0.0133 grams.

7. Average concentration of CaCO_3 remaining in solution in treated tests = 0.1760 grams (by analysis).

8. Total scale precipitated in treated tests = $0.3350 - 0.1760 = 0.1590$ grams.

9. Weight of non-adherent scale in treated tests = $0.1590 - 0.0133 = 0.1457$ grams.

Inhibition of Total Scale =

$$100 - \left(\frac{0.1590}{0.2650} \times 100 \right) = 40 \text{ percent}$$

Inhibition of Adherent Scale =

$$100 - \left(\frac{0.0133}{0.0887} \times 100 \right) = 85 \text{ percent}$$

Average deviation between tests = 1.4 percent.

Calcium Sulfate Tests

1. The scaling solution contains 50,000 parts per million NaCl and 10,000 parts per million of CaSO_4 . Therefore, each 250 ml portion contains 2,500 grams of CaSO_4 .

2. Average weight of adherent scale on untreated control rotors = 0.5751 grams.

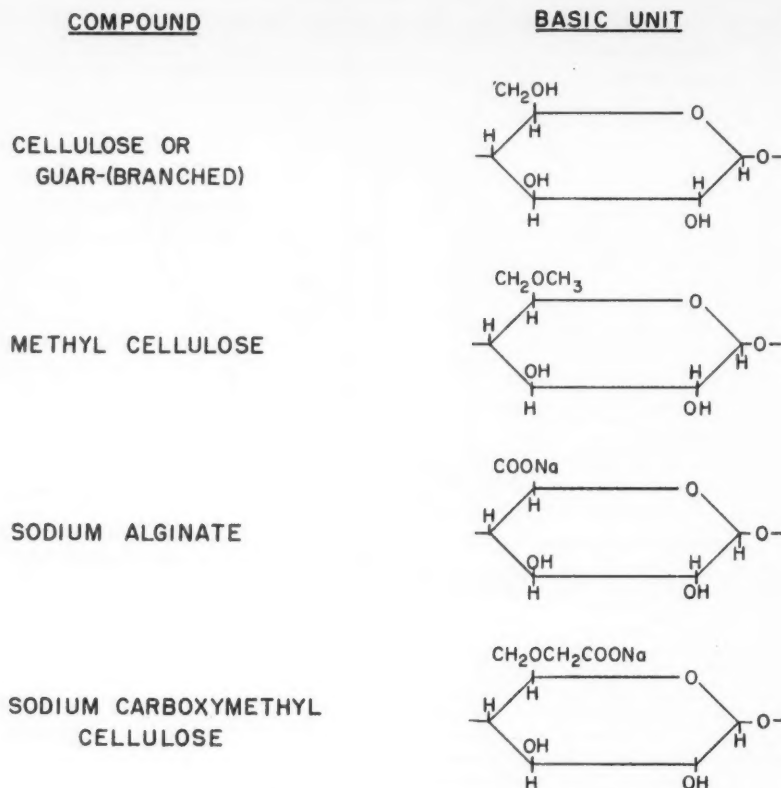


Figure 6—Basic structural units of some ineffective colloids compared to that of sodium carboxymethyl cellulose.

3. Average weight of adherent scale on rotors in treated tests = 0.4946 grams.

Inhibition of Adherent Scale =

$$100 - \left(\frac{0.4946}{0.5751} \times 100 \right) = 14 \text{ percent}$$

Average deviation between tests = 2.5 percent.

Results and Discussion

Laboratory Tests

Untreated. A series of tests were made with varying concentrations of scaling salts but with no inhibitors present. The range of concentrations tested and the relation of adherent to non-adherent scale in untreated tests are indicated by Figures 4 and 5. The total precipitated at any concentration is the sum of adherent plus non-adherent scales. In the carbonate tests, most of the scale was non-adherent. In the sulfate tests, somewhat more than half of the scale was adherent at the high concentrations.

In these tests the ratios of sodium chloride to calcium carbonate and calcium sulfate were held constant. No attempt has been made to explore the effects of varying the ratios.

Single Inhibitors. Summarized test data are tabulated in Tables 1 through 3. The polyphosphates provided good inhibition of calcium carbonate as was expected. Some commercial blends of polyphosphates have given even better results and tend to resist reversion to the orthophos-

phate form better than do the single compounds reported here.

Inhibition of calcium sulfate deposition by 20 ppm of the polyphosphates is poor. The results confirm field observations especially where high temperatures exist. Some published data⁷ indicate several molecularly dehydrated phosphates are able to delay precipitation of CaSO_4 at room temperatures, especially when used at 25 and 50 ppm.

Three sodium salts of ethylene diamine tetra acetic acid were tried with little success. Under alkaline conditions and in concentrations high enough to chelate an appreciable portion of the calcium ions present, agents of this type may be effective, but expensive.

The surface active agents were disappointingly poor at low concentrations. As shown in Table 2, none of the agents tested were appreciably effective.

In Table 3 are listed results with a variety of organic substances which generally form colloidal solutions in water. None of these were very effective in low concentrations against calcium carbonate. However, scale precipitated in the presence of such colloids tends to be softer than usual and more easily removed.

Attention is directed to the excellent results obtained with sodium carboxymethyl cellulose in the calcium sulfate test. The data are typical of several dozen laboratory tests that have been made. No other compound has been found which will, in equally low concentration, inhibit

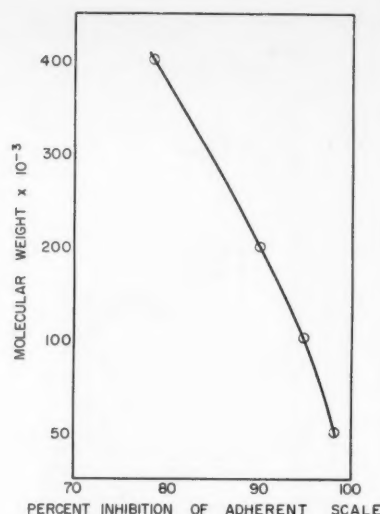


Figure 7—Effect of molecular weight on the ability of sodium carboxymethyl cellulose (20 ppm) to inhibit calcium sulfate scale. Molecular weight data were supplied by the manufacturer.

the deposition of calcium sulfate as well as the sodium carboxymethyl cellulose. This is rather surprising in view of the structural similarities of many agents tested. The structural features of several colloids are compared in Figure 6. All these products are long-chain polymers consisting of ether-linked units of isomeric configuration. The guar gum differs from cellulose in possessing single-membered branches on alternate units. Methyl cellulose has a methoxyl group substituted on about 30 percent of the hydroxyls. Sodium alginate contains the sodium carboxyl group at the 5 position. As explained above, none of these are effective against calcium sulfate. The effective agent contains the sodium carboxymethyl group and this appears to be the important difference. Hydroxyethyl substituted cellulose and some other variations have been tried without much success.

Several types of sodium carboxymethyl cellulose are available but are not equally effective. For example, the molecular chain length or molecular weight has an appreciable effect. This is shown in Figure 7. The high molecular weight materials gave poorest results. This is probably due to the simple fact that in equal weight concentrations the high molecular weight materials provide a fewer number of molecules per unit volume of solution than the low molecular weight types. For this reason it appears that a comparison of all the colloids should be made on an equimolar basis. This was not attempted since most of the colloids are not available in a range of known molecular weights. An eight-fold variation in molecular weight of the sodium carboxymethyl cellulose, from about 50,000 to 400,000, produced a change in inhibiting efficiency of about 20 percent. Assuming this relation holds for other colloids, it appears doubtful that any of those tested could approach the effectiveness of sodium carboxymethyl

TABLE 1—Scale Inhibition with Sequestrants

Compound	Calcium Carbonate			Calcium Sulfate	
	Conc., PPM	Percent Inhibition		Conc., PPM	Percent Inhibition, Adherent Scale
		Total Scale	Adherent Scale		
Sodium Septameta Phosphate.....	10	40	85	20	14
Sodium Hexameta Phosphate.....	10	49	75	..	..
Di-metallic Polyphosphate....	10	47	89	20	25
Sodium Tripoly Phosphate.....	10	38	90	20	39
Ethylene Diamine Tetra Acetic Acid (Sodium Salt).....	10	2	1	20	0

TABLE 3—Scale Inhibition with Colloids

Compound	Calcium Carbonate			Calcium Sulfate	
	Conc., PPM	Percent Inhibition		Conc., PPM	Percent Inhibition, Adherent Scale
		Total Scale	Adherent Scale		
Sulfited Tannin.....	10	9	49	20	15
Sodium Ligno Sulfonate.....	10	0	54	20	8
Irish Moss (Seaweed Extract).....	10	0	47	..	..
Sodium Alginate (Seaweed Extract).....	10	31	44	20	0
Sodium Carboxymethyl Cellulose....	10	20	39	20	100
Sodium Carboxymethyl Cellulose....	..	..	..	10	95
Polyacrylic Acid.....	..	..	..	20	0
Sodium Polyacrylate.....	..	..	..	20	13
Guar Gum.....	..	..	..	20	0
Methyl Cellulose.....	..	..	..	20	0

cellulose even if the optimum molecular weight were found.

It should be pointed out that some of the agents found to be ineffective may have some beneficial effects under less severe conditions. For example, subsequent to this study, some data published by McCartney and Alexander⁸ indicated that colloidal materials having regularly spaced ionized carboxyl groups on a chain structure greatly retard crystallization of calcium sulfate. Polyacrylic acid was shown by their work to be quite effective at room temperature but failed when heated to 158 F. The authors concluded that such polymers are strongly adsorbed on the faces of crystals, slowing or stopping crystal growth. Some action of this sort is postulated for sodium carboxymethyl cellulose. Figure 8 shows a comparison of calcium sulfate crystals precipitated with and without the presence of sodium carboxymethyl cellulose. The additive retards the growth of crystals to the extent that they remain dispersed and in apparent solution. Why the material is more effective on calcium sulfate than on carbonate is still under study. Possibly this is related to the different degrees to which the two minerals hydrate.

Blended Inhibitors. Most of the popular proprietary scale inhibitor compositions supplied to the oil industry were tested. The exact composition is not known in every case but the general natures of several are listed in Table 4. For comparison, a 50:50 mixture of sodium carboxymethyl cellulose and sodium tri-

TABLE 2—Scale Inhibition with Surface Active Agents

Compound	Calcium Carbonate			Calcium Sulfate	
	Conc., PPM	Percent Inhibition		Conc., PPM	Percent Inhibition, Adherent Scale
		Total Scale	Adherent Scale		
Fatty Amide Sulfonate.....	10	0	0	20	0
Alkyl Aryl Sulfonate.....	10	0	0	20	0
Acylated Amino Alcohol.....	10	2	0	20	0

TABLE 4—Scale Inhibition with Mixed Compounds

Compound	Calcium Carbonate			Calcium Sulfate	
	Conc., PPM	Percent Inhibition		Conc., PPM	Percent Inhibition, Adherent Scale
		Total Scale	Adherent Scale		
Seaweed Extract and Polyphosphates....	10	26	94	20	34
Tannin (75 percent) and Polyphosphates (25 percent).....	10	37	88	20	20
Surface Active Agents and Polyphosphates....	10	16	83	20	0
Cactus Extract and Polyphosphates....	10	27	78	20	0
Cactus Extract and Polyphosphates....	..	..	..	200	60
Sodium Ligno Sulfonate and Polyphosphates....	..	..	..	20	28
Sodium Carboxymethyl Cellulose (50 percent) and Sodium Tripolyphosphate (50 percent).....	10	44	92	20	95
Sodium Carboxymethyl Cellulose (50 percent) and Sodium Tripolyphosphate (50 percent).....	..	..	..	10	88

polyphosphate is also listed. Most of the proprietary blends provided good inhibition of calcium carbonate, but all were poor in the calcium sulfate test. Several could be made to work fairly well by increasing the concentration to high levels.

The mixture of sodium carboxymethyl cellulose and polyphosphates provided excellent inhibition of both types of scale. It is interesting to note that substitution of polyphosphates for up to 50 percent of the sodium carboxymethyl cellulose did not proportionately reduce effectiveness against calcium sulfate.

Inhibitor Formulation and Field Application

Laboratory data on performance of the mixed compound were applied to the development of practical inhibitor formulations. Practicality with respect to oil field operations means a material must be easily applied, be stable enough for storage under extremes of weather conditions, and be sufficiently low in cost to permit use in large volume operations.

Simply dissolving the inhibitor components in water for shipment to the fields was found to be impractical, since concentrated solutions develop extremely high viscosities. Most of the early field tests were made by using a dry-powder mix of the sodium carboxymethyl cellulose and polyphosphate. The powder was dissolved on location to make a stock

solution which was metered into the system under treatment. A special, fast-dissolving grade of the sodium carboxymethyl cellulose was provided to facilitate preparation of the stock solution. Field results were quite favorable with about a 5 to 1 success ratio. A few failures resulted from unknown causes and a few partially successful treatments apparently suffered from partial loss of effectiveness due to bacterial decomposition of stock solutions.

To eliminate mixing and storage of stock solutions, a solid composition was developed which utilizes a binder and solution rate control agent. This is made into the form of 3-inch diameter balls which are applied with bypass feeders. Actually, two ball formulations with varying proportions of components have been used. Both have proven successful, especially for prevention of calcium sulfate or mixed sulfate and carbonate scales in heater treaters. Some typical treating results are given in Table 5. It has been found important that treatment be applied nearly continuously due to the rapid replacement of water in the treaters.

Pellets, one-half inch diameter and smaller, are used for prevention of sub-surface scale. The pellets are batch lubricated into the casing annulus and flushed down with produced fluids. Additions are made daily or once or twice

a week. Manufacturing difficulties have limited production of the pellets and kept the cost undesirably high. Even so, they have proven to be the most economical method of controlling subsurface deposition of calcium sulfate in one field. In that field of seventy wells it is estimated that an annual saving of \$18,000 will result from use of this type of inhibitor.

Recent formulation work has yielded a combination consisting of the scale inhibitor and a field-proven, oil-soluble corrosion inhibitor. Since corrosion and scale deposition are often present in the same system, this promises to be a useful product.

Conclusions

1. Mineral scales are troublesome, costly, and can accelerate corrosion processes.

2. The causes of precipitation and deposition are fairly well understood.

3. An apparatus has been developed that permits rapid screening of scale inhibitors in the laboratory.

4. As a single class of compounds, the polyphosphates are most effective in low concentration for prevention of calcium carbonate scale deposition, especially at low temperatures.

5. Sodium carboxymethyl cellulose is the most effective single compound yet found for prevention of calcium sulfate scale deposition.

6. From the information gained by the laboratory studies, an inhibitor composition capable of inhibiting both carbonate and sulfate scales has been developed.

7. The powder, ball and pellet forms have proven successful in many field applications.

8. Combination corrosion and scale inhibitor compositions are a promising field for further research.

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DISCUSSION

Questions by Ben Sloat, Tulsa, Okla.:

1. Was Figure 8 prepared after an equal time interval of crystal growth for both normal calcium sulfate and calcium sulfate precipitated in the presence of sodium carboxymethyl cellulose?

2. Did you find that formulations in ball and pellet size gave the necessary continuous feed of product to the system? Was any attempt made to regularly determine the phosphate content of water treated with tripolyphosphate and sodium CMC?

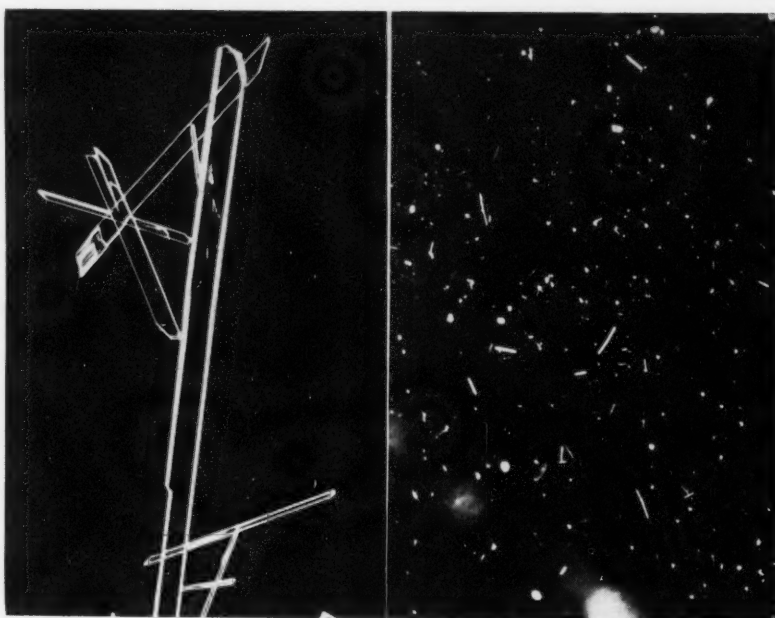


Figure 8—Photomicrograph of calcium sulfate crystals. Left: normal shape size. Right: precipitated in the presence of sodium carboxymethyl cellulose. Approximately 60X.

TABLE 5—Typical Results Obtained with Ball Type Inhibitor Treatment of Heater Treaters

Location	Type of Scale	Treating Rate, lb/300 bbl.	Estimated Reduction in Scaling Rate*
West Texas.....	Mixed sulfate and carbonate	1.8	78 Percent
New Mexico.....	Mixed sulfate and carbonate	0.5—1.0	90 Percent
Wyoming.....	Carbonate	1.0	72 Percent

* Percent reduction = $100 - \left\{ \frac{T_1 \times 100}{T_2} \right\}$ where T_1 and T_2 are time between cleanouts before and after initiating treatment.

3. Would the sodium carboxymethyl cellulose portion of the proposed formulation have any undesirable effects on the further processing or reinjection of the water being treated?

Replies by L. W. Jones:

1. Equal time for crystal growth was allowed. The solutions were heated to 165 F for three hours and allowed to cool approximately three hours.

2. The ball formulation seems to provide sufficiently continuous feed if some product is kept in the feeder pot at all times. Our field testing procedure consists simply of applying the compounds at a given rate for a period sufficiently long to provide unquestionable results. Chemical control analyses have not been attempted on a regular basis.

3. The concentration of residual sodium carboxymethyl cellulose in treated waters is very low. We have not experienced difficulty in re-injecting treated brines and do not anticipate any. However, we would not recommend addition of a colloid such as sodium carboxymethyl cellulose to a solids free water being injected into a tight sand. On the other hand, if the water is precipitating scale solids to the point that

treatment is required, the chemical could reduce plugging tendencies of the water.

Question by Glenn Ray Roberson, Standard Oil Co. of Texas, Houston Texas

Were temperatures measured on the coupon or in the water?

Reply by L. W. Jones:

1. The test temperatures are measured in the water. The skin temperature of the metal rotors is undoubtedly higher.

Question by Ed D. Parsons, Phillips Petroleum Co., Bartlesville, Okla.:

Inhibition of barium sulfate scale was not mentioned. Has this been studied?

Reply by L. W. Jones:

1. Fortunately, we have had very little trouble with this type scale. Inhibition of barium sulfate precipitation and deposition has been studied to a very limited extent. Due to the very low solubility of barium sulfate it is difficult to make quantitative studies such as those carried out with the calcium salts. From qualitative observations it appears that the subject scale inhibiting composition is at least as effective as several other products in delaying precipitation or dispersing barium sulfate.



Figure 1—Typical whisker growth. Each whisker is a single iron crystal which has grown along a preferred crystallographic axis. Approximately 10X.

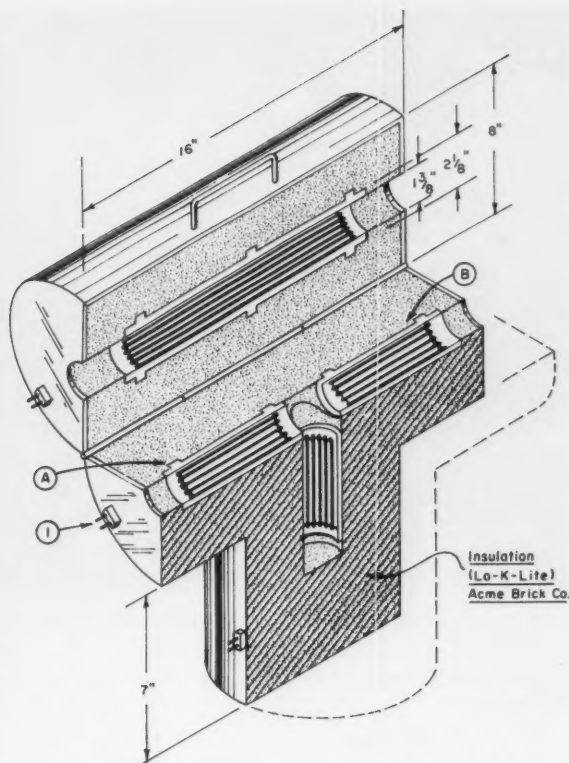


Figure 2—Modified combustion furnace of standard Hoskins laboratory tube type.

A Technical Note

Growth of Single Iron Crystals For Corrosion Studies*

By WILLARD F. BRICKELL* and EDWARD C. GRECO*

Introduction

A LABORATORY method is described here which was used to produce isolated single iron crystals with plane surfaces and essentially cubic dimensions. These crystals present several crystallographic planes and are considered desirable for electron beam studies of the surfaces after they have been exposed to corrosive environments of interest.

Isolated cubic crystals of iron were obtained when Brenner's^{1,2} method was modified in an attempt to produce larger iron whiskers. Brenner obtained pure iron whiskers by reducing ferrous halides (chlorides and bromides) with hydrogen gas at temperatures of 600 to 800 C.

Figure 1 shows typical whiskers grown in this laboratory. Each of these whiskers is a single iron crystal which has grown along a preferred crystallographic axis.

Abstract

A description is given of a laboratory method used to produce single iron crystals which have characteristic plane surfaces and essentially cubic dimensions. Such specimens are useful in corrosion studies where various crystallographic planes are of interest.

Several illustrations are included, one of which shows the size distribution of the cubic form crystals. The largest of this type crystal grown was 0.5 mm measured on an edge.

It is believed by General Electric Research Laboratory³ that an extremely small amount of iron oxide as a contaminant is responsible for the whisker type growth.

Apparatus

A modified combustion furnace of the standard Hoskins laboratory tube type, with a hinged top and used to contain the Vycor glass tube, is illustrated in Figure 2. An independent heater was provided to heat the tube side arm which con-

tained the chemically pure ferrous chloride. It is felt that this side arm provided the gradient conditions which promoted growth of isolated cubic iron crystals. The tapered ground joint near the center provided a means of placing the ferrous chloride in the bottom one-third of the side arm without contaminating the inside wall of the tube. A 0.1 cubic foot wet-test meter was used to measure the gas passing through the tube.

A scrubber containing sodium hydroxide solution was placed between the furnace and the wet-test meter to remove the hydrogen chloride released by the ferrous chloride during the reduction reaction. The meter was used to adjust the rate of hydrogen through the reaction tube during the crystal growth period and cooling period. A constant temperature of 730 C was maintained in the center of the reaction tube by means of an iron-constantan thermo-

* Submitted for publication February 9, 1961.

* United Gas Corporation, Research Department, Shreveport, Louisiana.

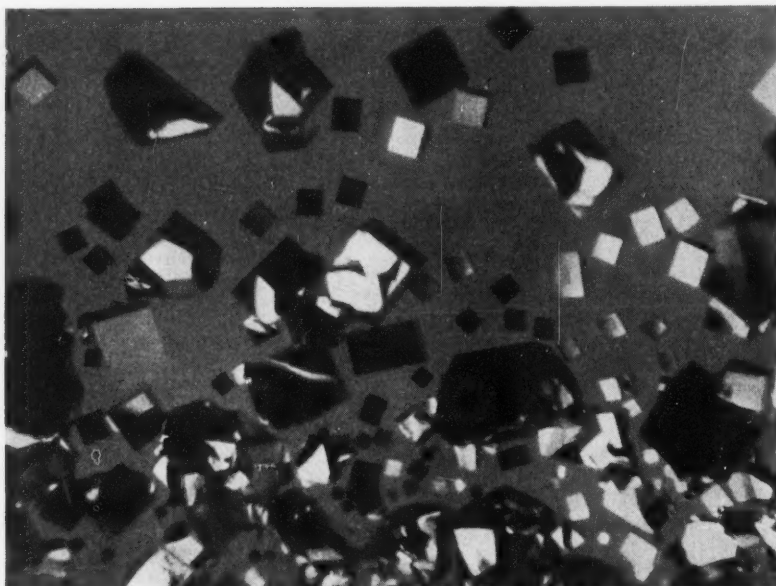


Figure 3—Size distribution of cubic form crystals. Approximately 25X.

couple connected to a temperature controller.

Procedure

As a conditioning procedure, hydrogen was passed through the reduction tube at the rate of 1.2 cubic feet per hour for two hours. The furnace temperature

was then increased from 25 C to 730 C and at this point, the auxiliary heater used to heat the side arm was set at 80 volts input or 520 watts. The hydrogen flow through the reduction tube was maintained at a rate of 1.0 to 1.2 cubic feet per hour for 12 hours, or during the crystal formation period. After this pe-

riod, the furnace was allowed to cool to room temperature. Throughout the cooling period, the hydrogen flow rate was maintained at 1.0 to 1.2 cubic feet per hour.

Results

When the tube was removed and opened, it was found that the majority of the crystals formed on the walls in the lower half of the side arm in a mass of long projecting whiskers which varied in size up to one millimeter in diameter and 1.5 inches in length (see Figure 1). Along the upper wall of the side arm, however, many completely isolated single crystals of iron formed. Figure 3 illustrates the size distribution of the cubic form crystals. The largest of this type crystal grown was 0.5 mm measured on an edge.

Conclusions

It is felt that a method has been developed to produce single iron crystals which have characteristic plane surfaces and essentially cubic dimensions. These can be used for corrosion studies where various crystallographic planes are of interest.

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Any discussion of this article not published above
will appear in December, 1961 issue.

Corrosion of Aluminum Alloys In High Purity Water in the Range 150 C - 340 C*

By D. F. MacLENNAN

Introduction

COMMERCIAL ALUMINUM, 2S, corrodes rapidly in pure water at temperatures above about 200 C.^{1,2} An experimental alloy, 157, developed by Krenz² corrodes at a much lower rate, after an initial period of rapid corrosion. Examination of corrosion product surfaces, formed after exposures of one to five minutes in 300 C water, has shown differences in the corrosion pattern of the 2S and the 157 alloys.³ Results suggested a relationship between the corrosion patterns and the distributions of second phase particles in the alloys. Additional information concerning the role of the second phase particles has been obtained by examining the corrosion product in cross-section while it is attached to the metal.

Experimental

The 157 alloy was obtained from Atomic Energy of Canada Limited and

★ Submitted for publication August 16, 1960.

has a nominal composition of 2.0 percent Ni, 0.5 percent Fe, 0.2 percent Si, remainder Al. The 2S aluminum was F temper and contained 99.0 percent or more Al with not more than 1.0 percent Fe and Si nor 0.2 percent Cu. The water used was distilled and passed through a demineralizer and had a specific resistance of about one megohm.

The cylindrical samples were 3/8 inch in diameter X 5/16 inch long with one flat face of each cylinder mechanically polished to 1/4 μ diamond. The samples were cleaned with trichlorethylene and weighed before exposure in the autoclave. The autoclave system and procedures have been described elsewhere.³

The general procedure was as follows: Samples were corroded for seven hours at temperatures ranging from 150 C to 340 C after which the outer surface of the corrosion product was coated with a thin layer of aluminum, by evaporation, in order to make this surface visible when photographed. Samples were

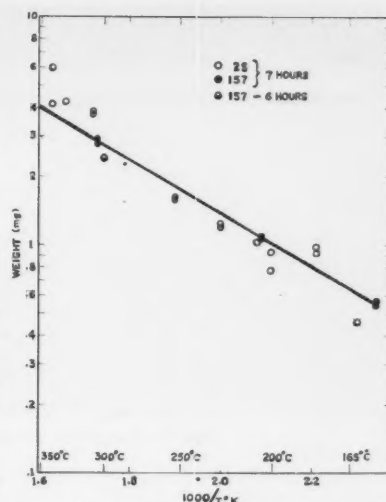


Figure 1—Weight gains of 2S and 157 alloys after exposure in pure water.

Abstract

Examination of the cross-section of the film on aluminum and its alloys, while attached to the metal, reveals that the second phase particles play an important part in the corrosion pattern. The 2S aluminum contains at least two types of second phase particles, one of which corrodes more rapidly while the other corrodes more slowly than the surrounding aluminum. The majority of second phase particles in the 157 alloy corrode more slowly than the surrounding aluminum.

6.4.2, 4.6.5, 3.2.3

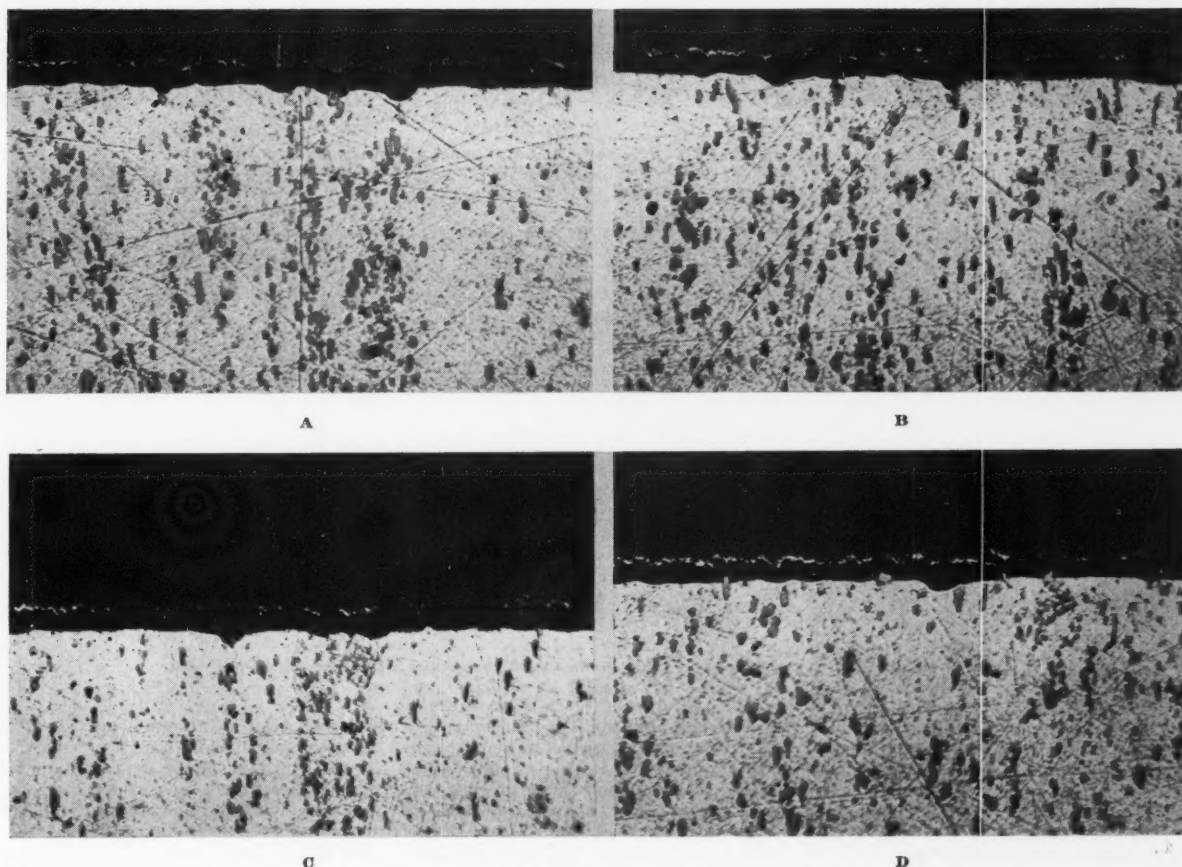


Figure 2—Cross-section of 157 sample exposed to 300C water for six hours. Four positions on the surface are shown at 1000X.

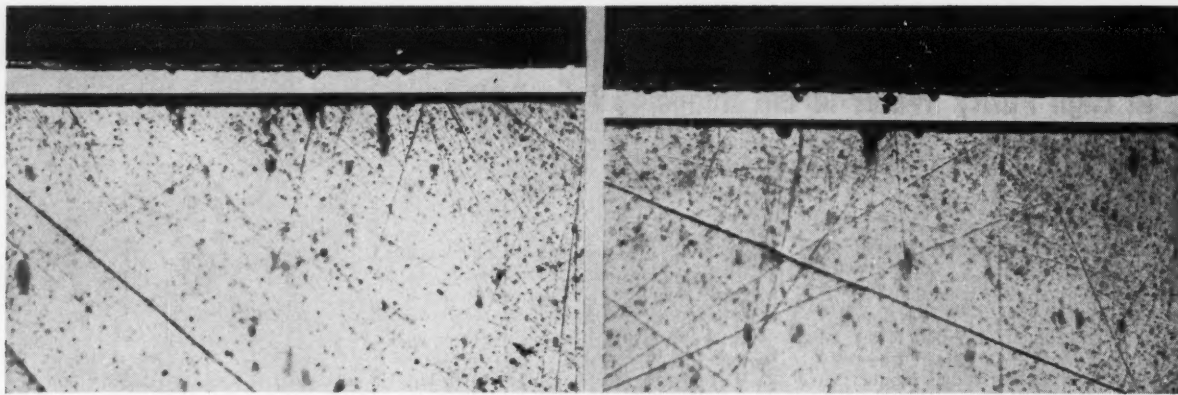


Figure 3—Cross-section of 2S sample exposed to 180°C water for 7 hours. Two positions on the surface are shown at 1000X.

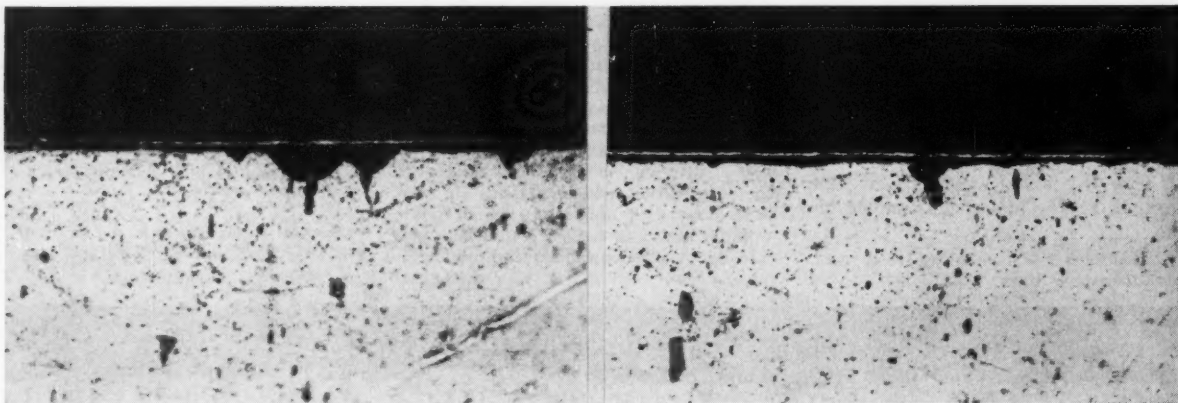


Figure 4—Cross-section of 2S sample exposed to 230°C water for 7 hours. Two positions on the surface are shown at 1000X.

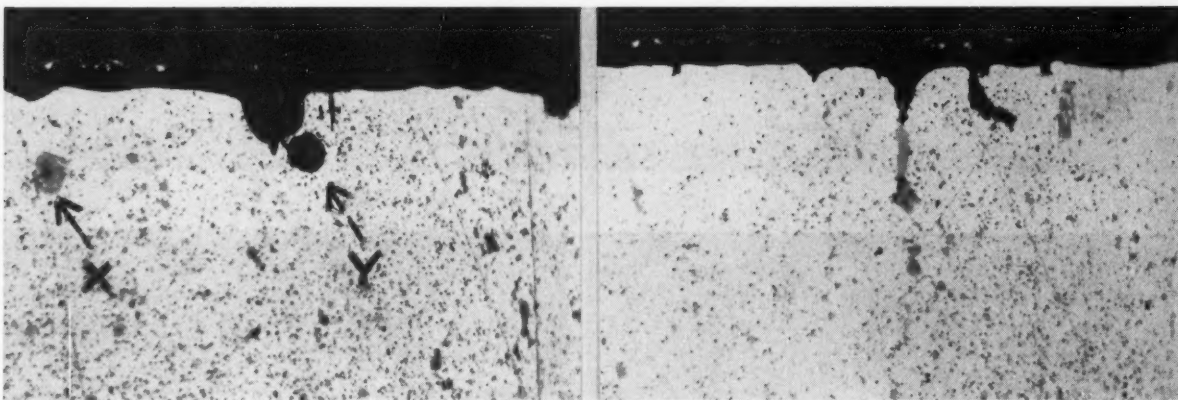


Figure 5—Cross-section of 2S sample exposed to 310°C water for 7 hours. Two positions on the surface are shown at 1000X.

mounted in plastic, cross-sectioned, polished, and then examined under an optical microscope.

Results and Discussion

Figure 1 shows a plot of weight gain per sample against the reciprocal of the absolute temperature. A straight line

has been drawn through the points representing the 157 samples. The 2S points are scattered but fall quite close to the 157 line indicating that at this exposure time the corrosion rates of both alloys are the same. Dillon⁴ also showed that in the early stages of corrosion, the corrosion rate was insen-

sitive to alloy composition and his data cover a much wider range of compositional variation. If the data of Figure 1 are converted to mils penetration per year on the assumption that at 350°C the corrosion product is $\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$ while at 200°C and lower it is $\text{Al}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$, then reasonable agreement is obtained with

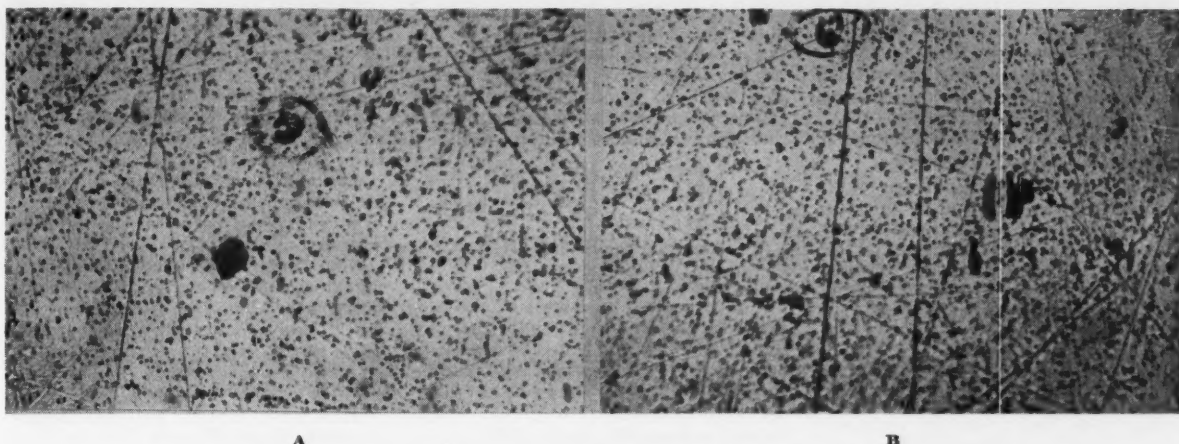


Figure 6—2S sample after treatment with solution which colors the second phase particles. Two positions on the surface are shown at 1000X.

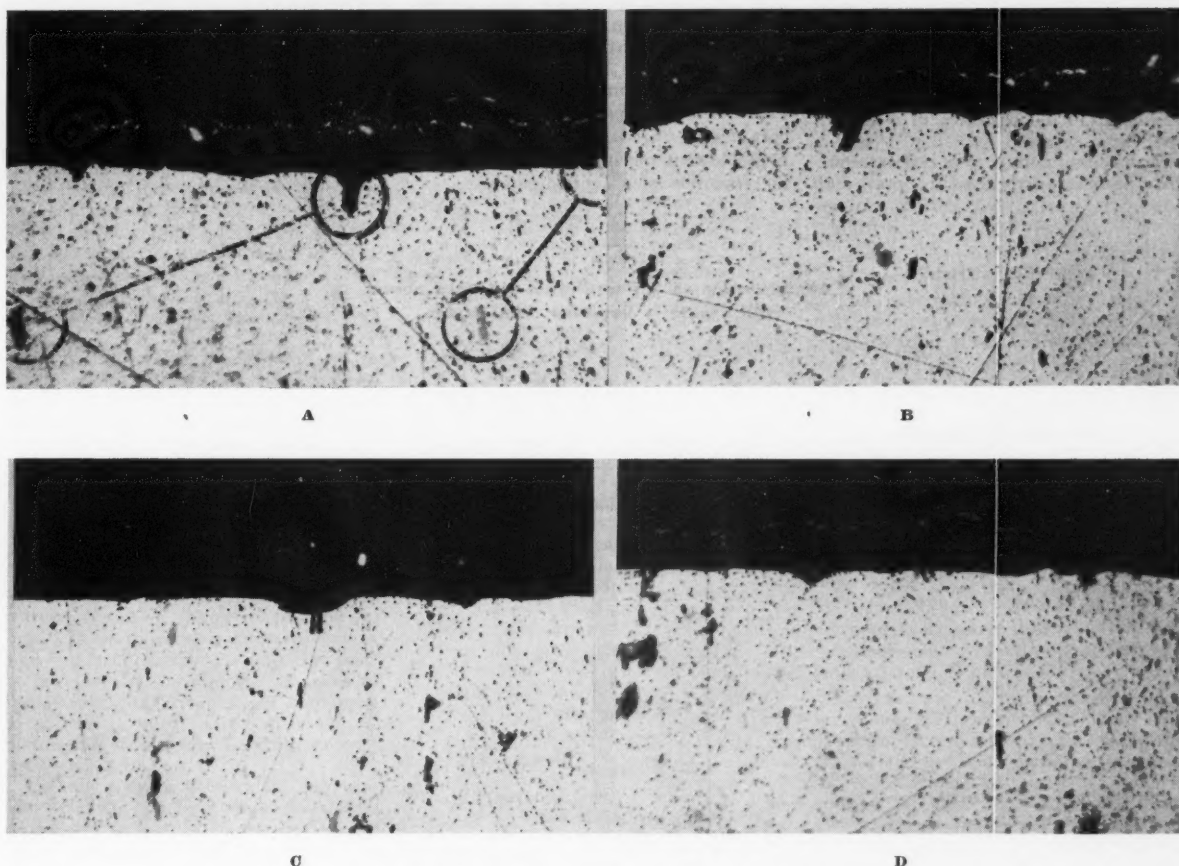


Figure 7—Cross-section of 2S sample exposed to 330C water for 7 hours. Four positions on the surface are shown at 1000X. The metal surface has been treated with the solution which colors the second phase particles.

Dillon's results. At 350 C a parabolic rate constant of 2.44 mils/year^{1/2} is obtained. Dillon's values range from 2.8 to 3.7

Figure 2 shows a cross-section of 157 sample which was exposed to 300 C water for six hours. The second phase particles are clearly visible in the metal. The outer surface of the oxide is relatively uniform. There are a number of

second phase particles in the oxide-metal interface. In some cases, A,B,C, there appears to be intensified corrosion of the aluminum around the particle. In other cases, D, the particles extend into the oxide with no apparent effect on the surrounding metal. There are also some depressions in the metal surface which apparently are not associated with particles. However there is the possibility that

particles may have corroded out of these positions. These observed differences could mean that there is more than one type of particle in this alloy.

The corrosion-promoting type of particle fits the model suggested by the examination at high magnifications of the inside surface of corrosion product films.³

In this earlier work a mechanism was proposed in which the second phase part-

icle and the aluminum in the immediate area form a local cell in which the aluminum is corroded rapidly and the reaction continues until the particle is isolated from the metal. The surface examination also suggested that a uniform distribution of these local cells is desirable for good corrosion resistance.

Figures 3-6 show cross-sections of 2S samples which were exposed to water for seven hours at various temperatures. It is seen that at all temperatures the metal-oxide interface is much more irregular than that of the 157 sample. The outside surface of the oxide, however is quite uniform.

Figure 3 shows a sample corroded at 180 C. It is seen that corrosion pits are associated with second phase particles. A thin oxide film covers the surface.

Figure 4 shows a sample corroded at 230 C. The corrosion on this sample is more severe but it is also centered around the second phase particles. The sample in Figure 5 was corroded at 310 C. Note the similarity in shape between the particle, X, and the hole, Y, which suggests that the hole may have resulted from the corrosion of a similar particle.

These pictures show that some second phase particles corrode more rapidly and

others more slowly than the surrounding aluminum. This suggests that there are two types of particles present. In order to investigate this possibility, attempts were made to identify the particles by coloring them. It was found that treating the surface with a solution of

- 1 part 28% HF
- 1 part 30% H_2O_2
- 2 parts conc. HNO_3
- 2 parts 10% $K_2Fe(CN)_6$
- 500 parts H_2O

for 15 seconds, caused some of the particles to darken. Two examples are shown in Figure 6. Note the similarity between the circled particles and particle X, in Figure 5. Particles of this shape are quite common to the 2S and on the treated surfaces they appear dark.

Figure 7 shows a sample corroded at 330 C. This sample has been treated with solution to distinguish between the particles. It is seen that the darker particles corrode more quickly and the lighter ones more slowly than the surrounding aluminum. Since particle X in Figure 5 is the type that turns dark and corrodes at the faster rate it is quite probable that the hole, Y, resulted from the corrosion of a similar particle.

The results indicate that in the early stages of corrosion, 2S and 157 alloy have approximately the same corrosion rate and that differences in final behavior is dependent on the behavior of the second phase particles and the surrounding metal. The second phase particles play an important part in the corrosion of these aluminum alloys. The 2S aluminum contains at least two types of second phase particles, one of which corrodes more rapidly while the other corrodes more slowly than the surrounding aluminum. The 157 alloy contains many more second phase particles than the 2S and a larger proportion corrode more slowly than the aluminum.

Acknowledgment

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Any discussion of this article not published above
will appear in December, 1961 issue.



NATIONAL ASSOCIATION of CORROSION ENGINEERS



Specification Format for Surface Preparation And Material Application For Industrial Maintenance Painting

A Report of NACE Technical Unit Committee T-6D⁽¹⁾
On Industrial Maintenance Painting,
Prepared by Task Group T-6D-2⁽²⁾ on Standardization
Of Scope of Painting Specifications

NACE TECHNICAL COMMITTEE REPORT Publication 61-1

Introduction

THE NEED for improved painting specifications has become more and more evident due to the great progress made in the coatings field.

The specification format created by this committee is not intended to be a finished painting specification but rather a plan to follow in drafting a set of complete, concise specifications for any plant.

By establishing clear cut standards in a form easily understood, it is the committee's hope to improve user-supplier-applicator relationship while at the same time getting a better paint job.

Scope

This specification shall govern materials, equipment and procedures for surface preparation and material application for all painting and coating performed at a typical chemical company. (This will serve as a general outline of specification form and suggested topics. The detailed contents and definition must be provided by the user for all items in the specification. Suggestions are made to provide a guide as to what subject matter the other items listed in the contents should include.)

Useable sources of detailed information are the reader's own established procedures and requirements, or NACE, SSPC, Federal Specifications, etc.

General

This item covers details of plant rules, safety requirements and general requirements within a plant.

Condensed Specification Method

The following Painting System Notation should be used as an abbreviated form of specifying and maintaining records of all painting and coating work.

⁽¹⁾ F. P. Helms, chairman, Union Carbide Chemicals Co., Texas City, Texas.

⁽²⁾ L. L. Sline, chairman, Sline Industrial Painters, Houston, Texas.

Abstract

This report gives a specification format for surface preparation and material application for industrial maintenance painting for a chemical company. Topics covered include the condensed specification method, surface preparation, pretreatment, material application, material description, comparison of proposed code system with typical present method, painting specifications, painting schedules and standards of inspection. A typical material description by user code is given.

5.4.6, 1.7.1

Surface Preparation:

N	None
B-1	Blast Cleaning White
B-2	Blast Cleaning Commercial
B-3	Blast Cleaning Brush Off
P	Power Tool Cleaning
H	Hand Cleaning
J	Steam Cleaning
S	Solvent Cleaning
F	Flame Cleaning
P	Acid Pickling
X	Other

Pretreatment:

N	None
W	Wash Primer
C	Chemical
X	Other

Film Thickness:

Dry Measurements

Method of Application:

B	Brush
S	Spray
H	Hot Spray
A	Airless Spray
R	Roller
T	Spot Brush
U	Spot Spray
X	Other

Surface Preparation

The designation "Surface Preparation" includes detailed standards of surface preparation in each category (sandblasting, hand cleaning, pneumatic tool cleaning, etc.).

Pretreatment

The designation "Pretreatment" includes such matters as requirements and procedures for application of wash primers, neutralizers and other surface pretreatments.

Material Application

The designation "Material Application" includes such topics on standards of painting application as brush, spraying—airless, cold and hot spray, roller application, etc.

Material Description

All painting and coating materials used in the plant are identified by code number as outlined below. Surface pretreatment is coded in one hundred series (100), primers in two hundred series (200), intermediate coats in a three hundred series (300) and finish coats in a four hundred series (400). Further breakdown of each hundred series could provide a system of identifying generic systems or types of materials.

For example, for two hundred primer, three hundred intermediate or four hundred finish series, all "tens" would be alkyls, all "twenties" would be phenolics, all "thirties" would be vinyls, all "forties" epoxies, all "fifties" chlorinated rubber, all "sixties" water emulsions, all "seventies" mastics, and so on. Plants that use more materials than the above suggested ranges will handle could expand the ranges or even add additional hundred series.

A complete account of typical material description by user code is to be found in Table 1.

Comparison of Proposed Code System With Typical Present Method

Typical Present Method (all interior steel)

1. Surface Preparation (Commercial Blast Cleaning)

TABLE 1—Typical Material Description by User Code

Charge	Type	Name	Mfg.	Data	Charge	Type	Name	Mfg.	Data
101	Wash Primer.....	Wualicote Wash Primer.	D	*	350	Chlorinated Intermediate..	Thompsonite.....	W	*
102	Wash Primer.....	Watts Wash Primer....	Sm	..	360	Acrylic Intermediate.....	Turnerite.....	U	..
103	Wash Primer.....	Pearless Wash Primer....	J	..					
104	Wash Primer.....	Sutton Wash Primer.....	Sl	..	410	Alkyd Tank White.....	Watson.....	G	..
210	Alkyd Red Lead Primer...	Wilson.....	G	..	412	Alkyd Gray.....	Wilmer.....	G	..
213	Alkyd Masonry Primer....	Tucker.....	G	..	419	Alkyd Masonry			
220	Phenolic Primer.....	Garrett.....	M	..	420	Enamel Green.....	Miller.....	G	..
230	Vinyl Metal Primer.....	Barton.....	D	..	422	Phenolic White.....	Gordon.....	M	..
240	Epoxy Primer.....	Warner.....	H	..	424	Phenolic Gray.....	Royal.....	M	..
250	Chlorinated Rubber Primer	Thompson.....	W	..	430	Phenolic Red.....	Grant.....	M	..
260	Acrylic Primer.....	Turner.....	U	..	431	Vinyl White.....	Tart.....	D	..
280	Zinc Silicate.....	Zilch.....	Z	..	435	Vinyl Yellow.....	What.....	D	..
310	Alkyd Intermediate.....	Wilsonite.....	G	..	440	Vinyl Tan.....	Tenner.....	D	..
320	Phenolic Intermediate.....	Garrettite.....	M	..	448	Epoxy White.....	Whitman.....	H	..
330	Vinyl Intermediate.....	Bartonite.....	D	..	456	Coal Tar Epoxy.....	Blackie.....	H	..
331	Vinyl High Build.....	Bartonite.....	D	..	457	Chlorinated Rubber Black..	Corn.....	W	..
340	Epoxy Intermediate.....	Warnerite.....	H	..	460	Chlorinated Rubber Blue..	Wheat.....	W	..
341	Epoxy High Build.....	Warnerite.....	H	..	467	Acrylic White.....	More.....	U	..
					470	PVA Blue.....	Less.....	U	..
						Asphalt Base Mastic.....	Yours.....	C	..

* Any data available would go in this space.

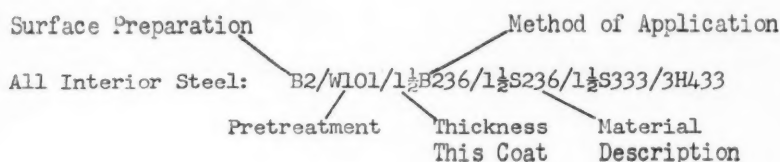


Figure 1

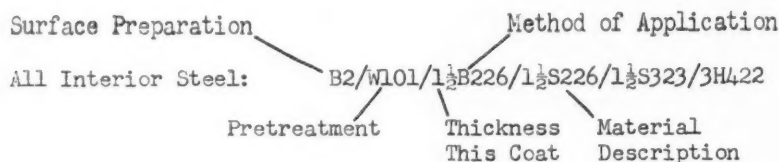


Figure 2

2. Apply one coat of "Wualicote" wash primer, manufactured by "D" Paint Company.

3. Apply by brush application one coat of "Burton" vinyl metal primer red, manufactured by "D" Paint Company. Mil thickness of primer is 1½ mils dry.

4. Apply by spray application one coat of "Burton" vinyl metal primer red, manufactured by "D" Paint Company. Mil thickness of primer is 1½ mils dry.

5. Apply by spray method one coat of "Bartonite" vinyl intermediate greencoat as manufactured by "D" Paint Company. Mil thickness of finish coat is 1½ mils dry.

6. Apply by hot spray method one coat of "Walter" vinyl finish vermilion manufactured by "D" Paint Company. Mil thickness of finish coat is 3 mils dry.

Proposed Code System. The proposed code system is shown in Figure 1.

Painting Specification

The following painting shall be done in accordance with company specification entitled "Specification for Surface Preparation and Material Application for Contract Painting Work."

Project: Building 62

Scope of Work: All Interior Steel and Masonry Surfaces

Painting Schedule:

1. Structural Steel: B2/W101/1½B-226/1½S323/3H422
2. Ceiling (Masonry): H/N/S465
3. Walls (Masonry): H/N/S266/Dado S469
4. Piping: B2/W101/1½B226/1½S-323/3H424
5. Stairways: B2/W101/1½B226/1½S-323/3H425
6. Underside of Floor Plate: B2/W-101/1½B226/1½S323/3H427
7. Top Side Floor Plate: B2/W101/1½B226/1½S323/3H427
8. Pumps and Motors: B2/W101/1½B-226/1½S323/3H426
9. Floors (Masonry): H/N/S213/S419

For an example of the above, refer to Figure 2.

Standards of Inspection

The designation "Standards of Inspection" includes the defining of inspection methods and inspection equipment to be used.

Laboratory and Service Evaluation Of Aluminized Steel Wire*

By JANE H. RIGO

Introduction

ALUMINIZED STEEL was first prepared some 60 years ago, thus uniting the strength of steel with the corrosion resistance of aluminum. In the interim several application methods have been developed including hot dipping, spraying, plating, annealing lacquers, calorigizing and cladding. Currently hot dipping is the most popular commercial process owing to its economy and versatility.

Basis of hot dipping's versatility is the number of processing variables¹ which can be controlled advantageously, (see Figure 1). These schematic graphs demonstrate that tensile strength can be augmented by: a. increasing the carbon content, b. and/or increasing percent cold work of the steel wire, c. lowering the bath temperature.

A decrease in percent elongation is noted when the carbon content and/or the percent of cold work are increased. A simple expedient for a limited increase in coating weight is to increase the coating speed.

Aluminized steel wire is composed of a steel core, an alloy layer, and an outer wash metal layer (see Figure 2). The alloy layer² is a diffused structure formed at temperatures below the melting points of the several composite phases. The wash metal or coating metal layer is a coating solidified from the molten state. For good corrosion resistance the alloy layer should be thin, uniform and flexible. About 7 percent silicon by weight maximum is commonly added to the bath to retard the growth of the alloy layer. The wash metal must be concentric and continuous.

Corrosion Resistance

Corrosion resistance of metallic items can only be determined under exposure conditions which simulate prospective service. Accelerated test data are worthless and often misleading due to a lack of reproducibility and realism. Consequently, American Steel & Wire Division of United States Steel Corporation has established exposure sites independently or cooperatively at the four geographical locations shown in Table 1. These sites represent marine, industrial and semi-rural environments.

Two of these locations have been rated³ for relative corrosivity with respect to steel and zinc. The other sites will eventually be rated, since they are

included in the new calibration program initiated in 1960 by ASTM Committee B-3, Subcommittee VII on Weather. None of the lots have been rated with respect to aluminum. If such a calibration were feasible, the information should be interesting in view of the conclusions drawn from the 1959 ASTM report³ that the "relative corrosivity of atmospheres might be different if still other metals were used as calibration specimens; therefore, it is necessary to state the metal used when reporting relative corrosivity of atmosphere."

According to the data in Table 1, the severest test site calibrated is the 80 ft. lot at Kure Beach, North Carolina, when steel and zinc are the test metals. The corrosivity of the 800 ft. Kure Beach lot



About the Author

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Abstract

The development of aluminized steel is outlined briefly. Results are reported of outdoor tests made on aluminized steel wire in marine, severe marine, severe industrial and semi-rural atmospheres. Proposed and current specification tests for aluminized steel which involve utilization of corrosion principles are discussed. Although the order of superiority of aluminized steel in atmospheric corrosion resistance compared to a zinc coating of equal coating thickness is not yet fully established, current information indicates that it will be substantial.

53.2, 62.3, 22.2

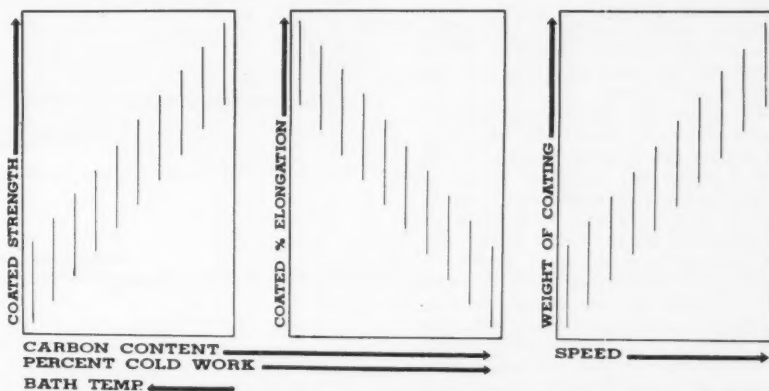
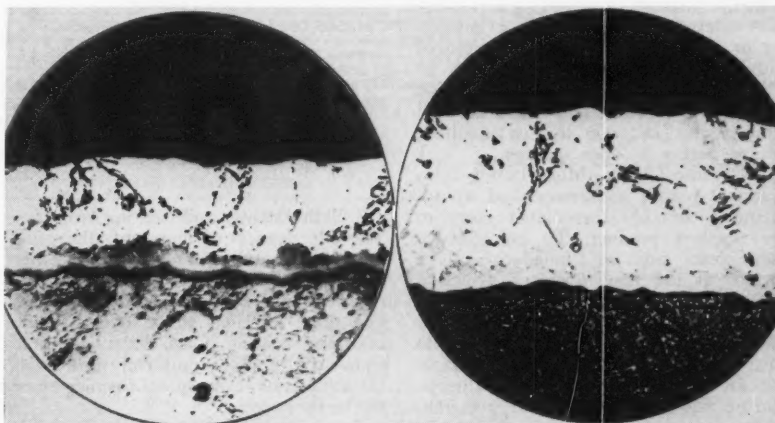


Figure 1—Influence of processing variables on mechanical properties and coating weight of aluminum coated steel.



Low Carbon Steel High Carbon Steel
Figure 2—Photomicrographs showing structure of aluminized steel wire.

* Submitted for publication September 15, 1960. A paper presented at a meeting of the Southeast Region, National Association of Corrosion Engineers, Atlanta, Georgia, October 6-7, 1960.

is only slightly higher than South Bend, Pennsylvania.

Patina

When aluminized steel wires, unfabricated or fabricated, are exposed at the industrial and semi-rural test sites, the first visible change may be a relatively early appearance of a uniform, microscopically thin, reddish-gold surface discoloration called "patina." Patina has not been observed in the marine locations. It has been identified⁴ by electron and x-ray diffraction as a mixture of beidellite (sodium aluminum silicate), gamma iron oxide ($\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$) and iron-aluminum oxide ($14\text{Al}_2\text{O}_3 \cdot 86\text{Fe}_2\text{O}_3$). Examination of a patinaed surface under low magnification showed a sporadic distribution for the beidellite and a more uniform one for the oxides.

Two causative mechanisms for patina have been suggested. One theory attributes patina to the corrosion of iron-aluminum-silicon needles supposedly distributed throughout the coating. A second, and more likely, theory postulates that patina is a corrosion product of the steel base. It is deposited on the aluminum surface through small, often microscopic, cracks or pinholes in the coating. These cracks are sufficiently large to permit access of the corrodants to the base metal. Fortunately this discoloration does not detract from the service life of aluminized steel due to the self-limiting nature of the corrosion products, which rapidly fill the cracks and prevent further corrosion. Patina is not red rust since attack of the base metal is infinitesimal.

The preceding statements can be easily demonstrated by chemically removing⁵ the surface discoloration which is patina, and stripping the residual aluminum coating to reveal base steel free of attack. Such a procedure was followed in the examination of the very lightweight, (0.16 oz. per square foot) aluminized steel picket (see Figure 3). This procedure convinced the uninitiated who were misled by patina into concluding that the parent fabric was rapidly failing. Determination of the residual coating weight and metallographic examination also proved the falseness of this assumption.

In the interests of removing a possible sales deterrent, several avenues of inhibiting or eliminating patina were explored with the following results.

1. Fabricating Oils—Proper selection of a highly refined petroleum oil will temporarily (i.e., one to two months), inhibit patina in open storage.

2. Organic Clears—More lasting inhibition of patina is accomplished by applying a suitably formulated clear to the finished product. To be effective these clears must be applied to a clean surface as the final operation. Such a test roll of aluminized (0.23 ounces per square foot) steel woven fabric, partially post-coated with a methacrylate clear, was exposed for 1.3 years weathering in industrial Waukegan, Illinois. During this exposure the smaller methacrylate portion showed no patina, while the larger section, lacking the clear organic coating, did.

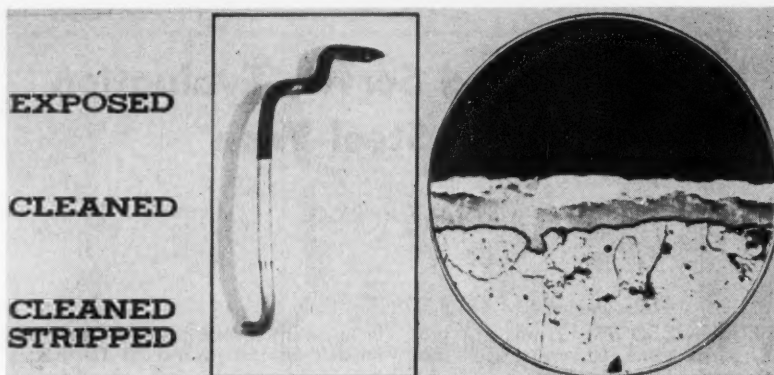


Figure 3—Nine-gauge aluminum precoated chain link. Weight of coating after four years was 0.115 oz per sq ft; exposure was at Waukegan, Illinois railroad right of way (time: approximately four years).

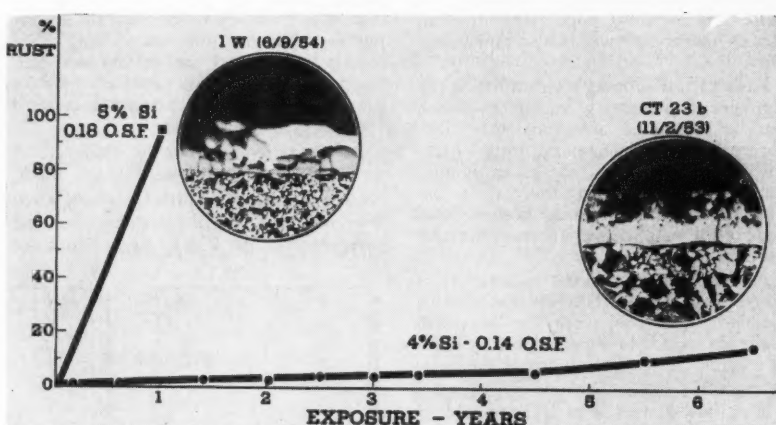


Figure 4—Aluminum coated steel stand. Exposure was in 800 foot lot at Kure Beach, N. C.

TABLE 1—Exposure Test Sites

Location	Atmosphere	RELATIVE CORROSIVITY STATE COLLEGE, PA. AS UNITY*							
		Cold Rolled Steel, Years				Zinc, Years			
		1	2	4	8	1	2	4	8
Kure Beach, N. C., 80 Ft. Lot.....	Severe Marine	13	20	23	..	5.7	5.0	4.4	4.1
800 Ft. Lot.....	Marine	1.8	1.7	2.3	2.4 ^b	1.7	1.4	1.2	1.1
Cleveland, Ohio ^c	Severe Industrial	...	...	...	..	..	..	..	..
Newark, New Jersey ^c	Severe Industrial	...	...	...	..	..	..	..	..
South Bend, Pa.....	Semi-Rural	1.5	1.5	1.6	1.7	1.5	1.6	1.7	1.8

* Quoted from ASTM proceedings, Vol. 59, Page 200. Report subcommittee VII, B-3.

^b Exposed for 5 years.

^c These lots included in second calibration program initiated April, 1960.

3. Bath Analysis and Coating Weight—The effectiveness of increasing the coating weight and/or incorporating other alloying elements in the aluminum coating bath are being currently explored. For these solutions to be effective, the resultant coating must have desirable concentricity and a uniformly thin flexible alloy layer. Subsequent forming must not be excessive.

At the present stage of development patina is accepted as an inherent characteristic of aluminized steel wire which

does not significantly shorten the expected life. Although methods of inhibiting patina are available at a price, customers are accepting aluminized steel products for many services as the result of an educational program on the ultimately harmless nature of patina.

Red Rust

The influence of a uniform and thin alloy layer on the resistance to red rust is presented in Figures 4 and 5. In both cases aluminum coated steel strands

were exposed in the 800 foot lot at Kure Beach, North Carolina. The premature failure of the one sample in Figure 4 is due to the irregularly thick and cracked condition of the alloy layer. In Figure 5 the thick, although uniform, nature of the alloy layer and the consequentially thin wash metal of the sample, fostered early failure. In contrast both good strands possessed a uniformly thin alloy layer and a relatively thick wash metal.

Figures 6 and 7 demonstrate the performance to date of aluminum coated field fence and barbed wire in an industrial exposure. Class 1 galvanized products were also included for comparative purposes. In both tests the time to 100 percent red rust for the Class 1 galvanized product is approximately 3.5 years. In contrast the aluminized steel products, although heavily patinaed, have developed less than 2 percent red rust, in the form of pinheads and pinpoints, after 6.5 years exposure. Another interesting observation was the complete absence of undercutting of the aluminum coating despite the fact that cut ends rusted within 24 hours of exposure. This observation is especially important when the cut ends must maintain sharpness to fulfill their function, (e.g., barbs on barbed wire).

Unfabricated wires are often exposed,

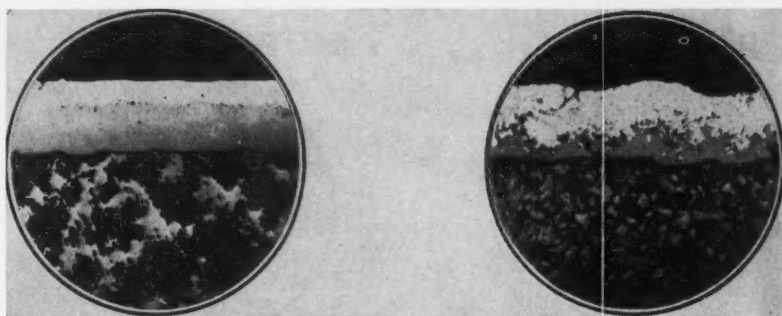


Figure 5—Aluminum coated (6 percent Si) steel strand. Exposure was in 800 foot lot at Kure Beach, N. C. Left: 0.19 oz per sq ft, 95 percent rust and stain after 1 year; right: 0.21 oz per sq ft, 1 percent rust and stain after 1 year and 10 percent after 3 1/2 years.

and a variety of measurements such as weight loss and tensile strength are periodically made. One test, involving 9 gauge steel and metallic coated steel wires, was initiated in 1956. Representative cross sections of the metallic coated test wires are presented in Figure 8 and particulars recorded in Table 2. In this test the chemical analyses of the base steels conformed to American Iron and Steel Institute specifications. By today's standards the two aluminized steel wires possess a relatively light weight of coating. Fortunately their coating thicknesses

approximate the coating thicknesses of the lighter weight zinc coatings which were produced by hot dipping and electrodeposition respectively. There is a difference in mechanical properties since no effort was made to process to a given specification.

Table 3 records the percent change in tensile strength of these sample wires after four years weathering in the various test lots. Sizable reductions in tensile strength are reported for the three bare steels; i.e., 10 to 20 percent for AISI Type C-1008, and 20 to 25 percent for

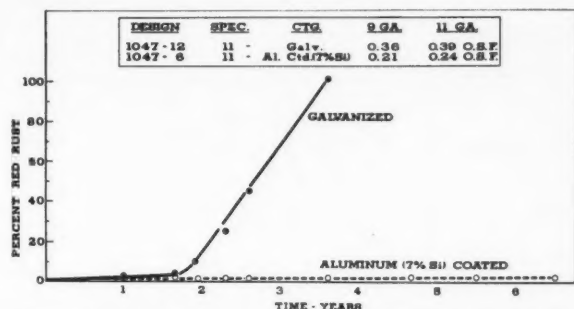


Figure 6—Relative corrosion resistance of two field fences in severe industrial atmosphere.

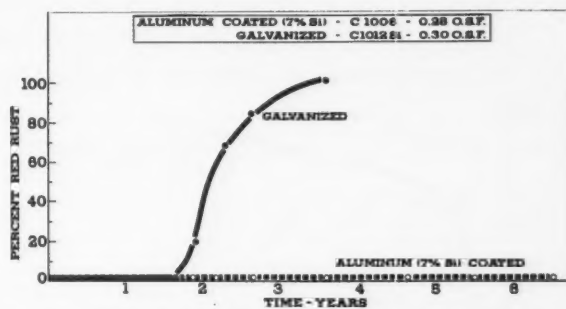


Figure 7—Severe industrial exposure (Cleveland, Ohio) of two types of Lyman 4-point barbed wire.

TABLE 2—Chemical Analysis and Mechanical Properties of 9 Gauge Test Wires

PLAIN STEEL												
AISI No.	ANALYSIS, PERCENT BY WEIGHT						MECHANICAL PROPERTIES					
	C	Mn	P	S	Si	Cu	Original Diameter	Breaking Weight, Lbs.	Tensile Strength	Percent Elong.-10"	Percent Red. of Area	
	C 1008.....	.045	.40	.012	.018	.01	.04	0.149"	1,245 Lb.	71,500 PSI	3.06	60.07
	C 1015.....	.16	.42	.010	.037	.14	.10	0.147"	1,739	102,600	1.4	48.4
	C 1015 Si.....	.18	.59	.010	.028	.01	.07	0.147"	1,793	105,700	1.17	41.93
METALLIC COATED WIRE												
STEEL BASE	COATING CHARACTERISTICS				MECHANICAL PROPERTIES							
	Type	Wt. O.S.F.	Alloy	Wash Metal	Original Diameter	Breaking Weight, Lbs.	Tensile Strength	Percent Elong.-10"	Percent Red. of Area			
C 1008.....	Al-5.1% Si, 1.8% Fe ^a Al-5.3% Si, 1.5% Fe	0.20 0.17	0.45 0.35	0.55 0.50	0.1507" 0.149"	989 1,010	55,867 58,000	13.87 10.4	91.7 73.07			
C 1015 Si.....	Hot Dip Zinc	0.46 1.15	0.60 0.60	... 1.05	0.147" 0.150"	1,170 1,154	69,033 65,350	11.7 17.1	62.23 67.45			
C 1015.....	Electrozinc	0.51 1.33	... ...	0.65 2.20	0.149" 0.152"	1,669 1,673	95,850 92,700	4.7 3.9	45.0 45.5		

^a Analysis of outer half of coating: Al-25 FPM at 1260 F.
Al-20 FPM at 1240 F.

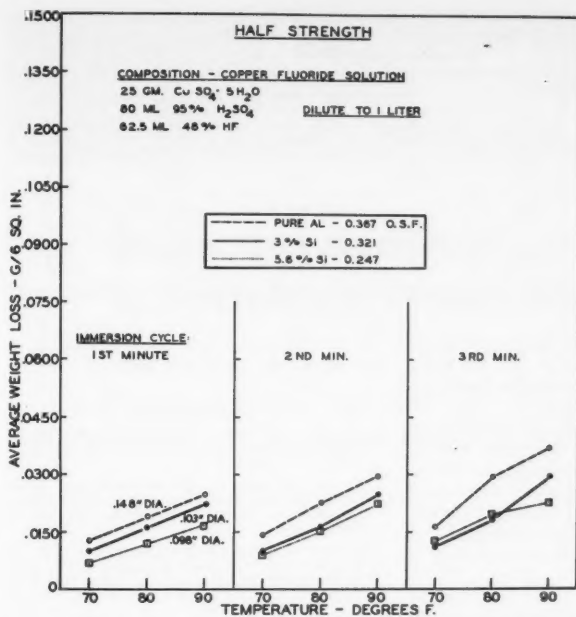


Figure 11—Effect of time and temperature of copper fluoride test (half strength) on the weight loss of aluminum coated steel wire.

garding weight loss and effect on mechanical properties of aluminized and galvanized welded fabric was obtained.

According to Figure 9 the original thickness of the aluminum coating was approximately three times the thickness of the zinc coating. After five years burial in concrete, the aluminized steel mesh had lost 95 percent of its original coating weight with some evidence of base metal attack after 3.5 years. In a similar burial period the galvanized mesh had lost only 40 percent of its coating weight with no base metal attack. In neither case were the original physical properties affected by the burial. Nor did the original base metal attack of the aluminized steel noted at 3.5 years appear to progress. Further exploration of this service should include an aluminized steel of heavier coating weight, 0.4 ounces per square foot minimum, in anticipation that this would allow sufficient aluminum for protection pending formation of the protective films which are reportedly characteristic of aluminum in direct contact with concrete.⁶

Cinders in direct contact with aluminized steel are very corrosive. The use of appropriate organic coatings to serve as a barrier between the cinders and the aluminized steel is recommended.

Specification Tests

The quality of an aluminum coating is dependent on its weight, its uniformity and its porosity. Uniformity may be defined as the degree of concentricity which the wash metal shows with respect to the alloy layer. Porosity refers to the voids in the coating extending to and exposing the steel base. Methods of measuring these characteristics must be reproducible and adaptable to mill control procedures. Despite considerable effort by several investigators the only measurement for which a method has been devised is the weight of coating procedure.⁷

Two typical tests proposed for porosity and uniformity measurements are the gas evolution test and a copper deposition test. The gas evolution test rates alumi-

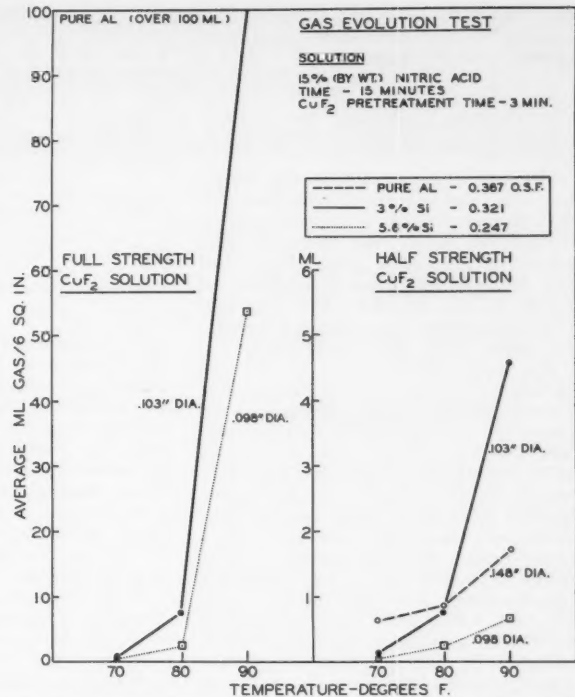


Figure 12—Effect of temperature and concentration of copper fluoride pretreatment on gas evolved in gas evolution test for aluminum coated steel wire.

nized steel on the basis of the number of cubic centimeters of gas evolved in three hours when a specimen of standard area is immersed in 15 percent by weight nitric acid at room temperature. This test is being evaluated by an ASTM task group, and the prospects of its being acceptable in its present form are negligible.

A copper deposition test devised by Kaiser Aluminum and Chemical Corporation⁸ involves dissolution of the coating and eventual copper deposition on the bare steel base. Laboratory experience indicates that the time to failure will be governed by the corrosion rate of the aluminum which in turn is dependent on the concentration and temperature of the test solution, the period of immersion and its own composition.

In Figure 10 the solution composition is as described by the investigators. Corrosion is expressed as the average weight loss in grams per 6 square inches. These

TABLE 3—Percent Change in Tensile Strength of 9 Ga. 0.1483" Wire After 4 Years Exposure

Exposure Site	AISI No. CTG. WT. OSF	C1008	C1015 SI	C1015	Al ₁		Al ₂		GALVANIZED		ELECTROZINC	
					C1008		C1015 SI		C1015 SI		C1015	
					0.20	0.17	0.46	1.15	0.51	1.33		
Marine:												
Kure Beach, N. C.—800 Ft.....		—19.6	—20.7	—25.7	—0.5	—1.9	+7.2	+5.7	—1.5	—1.2		
Industrial:												
Cleveland, Ohio.....		—15.4	—21.6	—21.6	+0.8	+1.0	+5.1	+6.8	—0.2	+4.8		
Newark, N. J.....		—10.5	—22.1	—20.1	+2.9	+1.0	—1.5	+6.8	—9.2	+3.4		
Semirural:												
South Bend, Pa.....		—9.1	—23.4	—20.5	+1.3	+1.2	+5.4	+7.4	—1.0	+0.3		

COATING ANALYSIS—OUTER HALF:

Al—5.1% Si, 1.8% Fe
Al₂—5.3% Si, 1.5% Fe

data show the following order of decreasing corrodability among the three coating analyses considered:

1. Pure
2. 3 percent Si-Al
3. 5.6 percent Si-Al.

For any coating analysis the weight loss at a fixed immersion time increased with temperature. At a constant solution temperature weight loss increased with successive immersion times. When the test solution was diluted as shown in Figure 11, the differences in weight loss previously noted were reduced in magnitude only.

An objectionable feature of the gas evolution test is the three hours required for completion. Figure 12 summarizes the results of an exploration to determine what quantity of gas would be evolved in 15 minutes if the test wires were pretreated for three minutes in the copper fluoride solution at given solution temperatures. These data indicate that a pretreatment involving partial removal of the aluminum coating will reduce the time required to perform the gas evolution test, where three cubic centimeters have been established as failure. It is obvious that further investigation is required, and the information contained in Figures 10, 11 and 12 are only indicative of procedures which may eventually be refined to a satisfactory state.

Conclusions

Aluminizing steel unites the strength of steel and the corrosion resistance of aluminum. Although the magnitude of its superiority in atmospheric corrosion re-

sistance compared to a zinc coating of equal coating thickness is not yet fully established, current information indicates that it will be substantial.

Patina, a uniform surface discoloration especially observed on severely worked or formed aluminum coatings, is an inherent characteristic of aluminized steel at its present stage of development. Patina is not detrimental to the life of the coating. It is not red rust nor does it promote red rust.

A procedure to determine the weight of coating on aluminized steel is a matter of record. Despite considerable exploration there are no rapid methods of measuring the uniformity and porosity of aluminum coating. This problem is complicated by the fact that uniformity and porosity will vary with the weight and composition of the aluminum coating as well as the method of manufacture.

Acknowledgments

Appreciation is extended by the author to A. E. Demse, J. A. Hoffman and

E. G. Schroedel for their assistance in accumulating pertinent data.

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TABLE 4—Percent Loss in Coating Weight of Tensile Specimens After 4 Years Exposure - 9 Gauge (0.1483") Metallic Coated Wire

Base Steel AISI No.	Type	Weight, O.S.F.	PERCENT LOSS IN COATING WEIGHT			
			Kure Beach N.C., -800 Ft.	Cleveland, Ohio	Newark, N. J.	South Bend, Pa.
C 1008,	Al ₁ Al ₂	0.20 0.17	35.2 35.3	23.5 23.5	17.7 41.0	11.8 23.5
C1015 Si,	Galvanized	0.46 1.15	100% Red Rust 31.3 40.0			
C1015,	Electro ZN	0.51 1.33	100% Red Rust 39.2 33.8			
					71.3	87.0 24.3
					60.0	92.3 25.6

Any discussion of this article not published above will appear in December, 1961 issue.



NATIONAL ASSOCIATION of CORROSION ENGINEERS



Protective Coatings In Petroleum Production

A Report of NACE Technical Unit Committee T-6E
On Protective Coatings in Petroleum Production*

NACE TECHNICAL COMMITTEE REPORT

Publication 61-2

Coatings in General

THIS REPORT is based on a survey of current practices in use by a number of companies engaged in the production of petroleum. It is designed to serve as a guide for the production superintendent, the petroleum engineer, and the field foreman in the selection of protective coatings and application methods. While in many cases several types of coatings and application methods may be recommended, each type of environment must be considered as a separate case, and the final choice must depend upon the economics involved. Included are recommendations for drilling equipment, producing equipment and storage tanks. Brief descriptions of various types of coatings most used in the oil field are given in order to familiarize the field man with their nomenclature and give him an idea as to their performance characteristics. This report attempts to cover only types of coatings which have been used successfully in petroleum production over a period of time. It does not cover some of the newer exotic coatings which are still considered to be in the experimental stage as far as their use in the oil field is concerned.

Types of Coatings and their Characteristics

Organic Coatings

Organic coatings are composed of pigments and vehicles. The vehicle, or carrier, consists primarily of a resinous binder, solvents, and perhaps driers, plasticizers, and stabilizers. These coatings change from the liquid to a solid film by several mechanisms:

1. Evaporation of solvent
2. Oxidation
3. Polymerization, either by internal reaction or reaction with an added "catalyst" or "activator."

The pigments, depending on which ones are contained in the plant, give such properties as inhibition of the metal sur-

Abstract

This report on protective coatings used in connection with petroleum production is based on a survey of current practices in use by a number of companies. It covers such topics as surface preparation, surface treatments and primers, application methods, inspection methods, coverage rates, painting for reflection, selecting a painting contractor, typical coating defects, design problems, and safety suggestions. Organic coatings discussed include oil, alkyd, chlorinated rubber, epoxy, bituminous, vinyl, silicone, coumarone-indene, acrylic, epoxy-coal tar and urethane. Inorganic coatings considered include cement, galvanized and metallized. Special environments discussed include hot surfaces, sour crude tanks, galvanized surfaces, light products tank interiors, and pipe lines. Sample specifications are included for tank painting. Photographs of coating inspection instruments are shown. 5.4.5, 5.4.2, 5.3.2, 8.4.3, 1.7.1

face (red lead and zinc chromate), reinforcing of the film, stabilization against sunlight attack, color, and controlled chalking (titanium dioxide). Organic coatings are usually classified according to the major type of resin contained in the vehicle. Commonly used coatings are:

a. Oil base, or oleoresinous. These consist of an oil (usually linseed, tung, soy bean, or castor), which is capable of being converted to a solid by reaction with the oxygen of the air. Metallic driers are added to accelerate this reaction. The film formed has very little resistance to chemicals and has higher permeability to water vapor and other gases than have other types of films. This permeability makes it a good binder for use in house paints, which if not somewhat permeable would blister and peel. An outstanding property of the drying oils is their ability to wet and adhere to steel, which accounts for their widespread use in primers. This property is particularly important in instances where it is not possible to remove all rust before painting.

b. Alkyd. These synthetic resins are made by cooking certain acids and alcohols along with varying quantities of drying oils. These drying oils impart flexibility to the resin; the more oil in the resin, the more flexible the coating will be; however it also follows that the more the oil "length" or content, the more the

coating will resemble the oleoresinous type. A good example of alkyd coatings is present day automobile enamels. The outstanding properties of alkyds are their gloss retention and stability to sunlight. It is estimated that 90 percent of all paints bought at oil field supply stores are alkyds of some type.

c. Phenolic. One of the first synthetic resins to find wide use in coatings was the phenolic, formed by reacting phenol with formaldehyde. Air-drying phenolics have better chemical resistance and more water resistance than alkyds, but they are less resistant to the effect of ultraviolet light, tending to yellow with age and to chalk more rapidly. The baked-on phenolics have shown outstanding performance as a lining material for well tubing, for prevention of both corrosion and paraffin deposition. Some operators specify lined tubing in all offshore wells for extra insurance against corrosion as a standard practice because of the tremendous expense of moving workover rigs to location.

d. Chlorinated Rubber. Chlorinated rubber resins are made by reacting chlorine with natural rubber. Coatings made from chlorinated rubber have very good resistance to alkalis, weak acids, and salt water, but must be modified and stabilized to give them resistance to sunlight. Their major use in oil production is in the coating of offshore platforms and barges.

e. Epoxy. These resins have been on the market since 1949 for the manufacture of coatings. They are derived from petroleum.

(1). **Catalyzed epoxy coatings.** A small amount of amine or polyamide catalyst or "activator" is added to the epoxy coating just prior to application. This causes a cross-linking of the molecules and curing of the coating. While these coatings set to touch in a few hours, several days are required for them to cure completely and develop their ultimate chemical resistance. Catalyzed epoxy

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TABLE 1—Costs Reduced to a Square Foot Basis for Various Weight Plates

Plate Thickness	Metal Wt. Per Sq. Ft., Lbs.	Total Surface Per 100 Lbs.	COST PER SQ. FT.	
			\$3.00/CWT	\$3.19/CWT
14 gauge.....	3.281	60.4 sq. ft.	4.96 cents	5.29 cents
12 gauge.....	4.531	44.4 " "	6.76 " "	7.20 " "
11 gauge.....	5.156	38.8 " "	7.75 " "	8.23 " "
10 gauge.....	5.781	34.7 " "	8.65 " "	9.20 " "
3/4 inch plate.....	7.650	26.2 " "	11.45 " "	12.15 " "
1/2 inch plate.....	10.20	19.6 " "	15.31 " "	16.30 " "

coatings have good acid resistance and very good alkali resistance, however their outstanding property is their excellent resistance to solvents. They are widely used for coating the interior of products storage tanks. In sunlight, they tend to develop rapidly (within 6 months) a surface chalk which will mast bright colors.

The catalyzed coating must be applied within a few hours after the addition of catalyst, otherwise it will set up in the can. Brushes and spray equipment used to apply these coatings must be cleaned thoroughly after use. After the epoxy has cured, there is no known way to remove it from equipment. The coating manufacturer should always be consulted before using an epoxy system for equipment which is to be immersed in either fresh or salt water.

(2). *Baking epoxies.* These coatings require heat to convert them to a solid film. Their characteristics resemble those of baked phenolics, and they are frequently combined with phenolics for lining well tubing.

(3). *Epoxy esters.* These products are formed by reacting epoxy resins with components of drying oils, such as linseed oil. While somewhat more resistant to chemicals than are alkyds, they also have less gloss retention.

f. Bituminous coatings. These coatings are made from coal tar or asphalt. They may be hot-applied, cut-back (dissolved in a solvent), or emulsions (particles dispersed in a non-solvent). Their widest use lies in protection of buried pipe. Some heavily filled bituminous coatings are used as a semi-insulating coating on LPG tanks. The coal tar coatings have much better resistance to moisture penetration, to attack by soil organisms, and to hydrocarbons than do most of the asphalts.

g. Vinyl. Vinyl coatings have very good resistance to acids, alkalis, oils, and salt water. Their adherence is poor unless special vinyl primers are used. For a vinyl system, a bright metal sand blast is necessary for best performance. Vinyl coatings have the lowest solids content (and highest chemical resistance) of any of the commonly used coatings, therefore multiple coats are necessary to build up adequate film thickness. Vinyls are probably the most used coating for offshore drilling and production equipment. Since they dry only by solvent evaporation, they can be re-dissolved in their same solvents (ketones and aromatic hydrocarbons). Vinyls are also widely used in the emulsion form (PVA) as wall finishes, concrete coatings, and asphalt sealers.

h. Silicone. Silicone resins, because of their thermal stability are used to make heat-resistant paints. These resins are quite expensive, therefore silicone coatings should be used only if other types of coatings are unsatisfactory. Aluminum-pigmented silicones perform well up to about 800 F. They are widely used on mufflers, heater stacks, and hot surfaces of that type. A white-metal sand blast is necessary for the silicones to perform properly. Two coats of silicone coating should be applied, with a heat-cure after the first coat.

i. Coumarone-indene. These resins are made from the chemicals coumarone and indene, which are derived from coal tar. Their main use is in preparing vehicles for aluminum paint. They are said to promote leafing of the aluminum pigments which gives a brighter finish. This is probably due to the fact that they are very low acid-content resins. High acid content resins, when used in aluminum paint, attack the aluminum pigment and destroy its luster; also this reaction causes gases to form and may go so far as to blow the lids off the cans during storage. Coumarone-indene resins turn yellow and deteriorate in sunlight unless protected by opaque pigment such as aluminum.

j. Acrylic. These thermoplastic resins are derived from natural gas. Their most familiar form is in the clear, solid plastic used for bomber noses and bubbles. In coatings, they are most commonly used in the form of water emulsions. However they also may be combined with vinyl resins to give the vinyl coatings a higher gloss, or they may be combined with alkyd as in the new long-life automotive enamels which are not supposed to require polishing. In the emulsion form, they are (1) excellent coatings for concrete because of their good adherence and resistance to alkali, and (2) excellent sealers for bituminous coatings to prevent the tar or asphalt from bleeding through finish coats.

k. Coal tar—epoxy. These catalyzed materials combine the excellent adhesion and water resistance of coal tar with the thermal stability of catalyzed epoxy coatings. They have a high solids by volume content (65-85 percent) and good stayput, allowing thick coatings to be applied in a minimum number of coats. Two coats of 8-10 mils each are recommended for most uses. The main uses of coal tar—epoxy coatings in oil production are for offshore equipment, mud tanks, equipment to be exposed to immersion in salt water (particularly boat bottoms), the exterior of pipe which is to be used un-

derground, and the interior of crude tanks. The coatings' high degree of impermeability to gases, particularly hydrogen sulfide, makes them well-adapted to protecting the vapor zones of sour crude tanks.

1. Urethane. These synthetic resins are just beginning to be used in this country, although they have been used in Germany for at least 10 years. Urethane coatings have not been widely applied in the oil fields. They are mentioned here because of testing work which is underway and which indicated that their very high abrasion resistance will make them applicable as lining for tubing in pumping wells, as well as coatings for sucker rods.

B. Inorganic Coatings

a. Zinc-Inorganic Coatings. The zinc-inorganic coatings are characterized by their extreme resistance to abrasion and severe weathering conditions. The coating consists of zinc in combination with compounds of silicon, and in the simplest terms can be considered a cross between galvanizing and a ceramic.

The zinc-inorganic coatings require good surface preparation. Where blasting is impossible, the coating manufacturer should be consulted as to the advisability of using a zinc-inorganic coating.

Coatings of this type contain zinc, and are therefore limited in their ability to withstand exposure to strong mineral acid and caustic solutions. One exception to this rule is the satisfactory performance of such coatings when exposed to high pH (top limit pH 12) lime-base drilling muds. The zinc-inorganic coatings have been used successfully for exposures involving weathering, extreme abrasion, immersion in alcohols, ketones, most chlorinated hydrocarbons, and the full range of finished petroleum products. Common usage includes offshore drilling platforms, sides and decks of barges, interior surfaces of petroleum tankage, decks of floating roof tanks, interior surfaces of clean-oil tankers, and as a permanent prime coat for chemical resistant coatings in chemical exposures.

While the materials as a class are easy to apply, details of application differ sufficiently from those connected with paints and conventional organic coatings that users should solicit aid during their initial application from manufacturers' representatives.

Where a long-life coating system is desired, the zinc-inorganics are often used as a prime coat for good quality organic coatings. Such a system usually has better performance than either the zinc-inorganic or the organic coating by itself.

b. Galvanizing. Galvanized steel is used by the oil industry for the same reason as in others, namely, because it offers very good protection against corrosion at a minimum cost. When galvanizing is reduced to a cost per square foot basis it is surprising that it is not more widely used. Galvanizing is sold on a steel weight basis.

This discussion refers to custom hot-dip galvanizing, done after fabrication, with the ASTM standard two ounces of zinc per square foot both sides. This is a much heavier zinc coat than the commercially available galvanized steel sold through the usual outlets. The cost of custom galvanizing ranges from \$3.00 to \$3.19 per cwt. This cost reduced to a square foot basis for various weight plates is as shown in Table 1.

The cost of galvanizing per square foot of surface is much lower than almost any type of surface preparation alone. It is only a fraction of the cost of a satisfactory sandblasting job. A rough estimate for application of any paint or coating is 5 cents per square foot per coat, so in some cases the galvanizing costs only as much as a single coat of paint.

Galvanizing must be applied over a clean steel surface. The steel is acid pickled and rinsed to remove all soluble salts, etc. Galvanizing is accomplished by dipping the clean steel into a molten bath of zinc at a temperature of from 840 to 860 F. The zinc coating formed is actually an alloy with the steel being galvanized. Next to the steel surface is an iron rich zinc alloy consisting roughly of 60 percent iron-40 percent zinc. The next layer is zinc rich alloy consisting roughly of 40 percent iron-60 percent zinc; the top layer is straight zinc, usually at least 98 percent pure zinc. Galvanizing then is not in the same class as ordinary protective coatings, but is actually a corrosion resistant alloy clad steel. ASTM standard galvanizing is referred to as two ounces per sq. ft. of surface, both sides; this is equivalent to 1.7 mils in thickness.

Smart fabricators are taking advantage of this economical surface preparation coupled with the corrosion resistant zinc surface. After fabrication, the zinc surface needs only to be solvent cleaned to further protect it with paint. If the surface contamination is just oil or grease, ordinary naphtha will be satisfactory. In some cases a special material is used over galvanizing to prevent it from tarnishing. This type of preservative requires more of a lacquer type solvent for removal. An excellent primer for galvanized metal is a phosphoric acid vinyl butyral "wash primer" such as the standard Navy formula WP-1. Any coating system will adhere to this surface. Other special galvanized primers are available—some good, some poor.

Bolted galvanized storage tanks have long been used by the oil industry. These tanks have given years of corrosion-free service. Even in areas handling very corrosive sour crude the galvanized surface has given about 5 years service before protection is dissipated and coating is required. At the present time there is a trend, because of proration, to install small tanks. In order to lower the initial investment, plain welded tanks are often purchased. Unless this is necessary because of pressure reasons, the practice is false economy. In just a few years the maintenance necessary on a plain steel tank will be many times the initial saving.

The use of galvanized metal really shows its merits the nearer one ap-

proaches the coast. The use of galvanized fittings has been proven in marine service. Galvanized steel is very satisfactory and is used by the oil industry for miscellaneous fittings, catwalks, guard rails, stairs, piping on marine equipment and many other applications.

When purchasing galvanized sheet roofing or siding, make certain that the sheet is stamped with the American Hot Dip Galvanizers Seal of Quality.

c. Metallizing. Metallizing is a process by which metals such as Monel, aluminum, zinc and any other material that can be drawn in wire form, may be sprayed by the use of oxygen, acetylene and air, on a properly prepared surface (see Figure 1). It also can be sprayed on wood, concrete, and other surfaces; however, it is most commonly used on metal for either corrosion or wear resistance.

The most important factor in the process is surface preparation. This means a thoroughly cleaned and roughened surface has to be obtained by sandblasting or grit blasting. When this has been achieved, the desired metal and its thickness are determined by the specific uses for which the equipment is to be subjected.

The most widely used sprayed metal coatings in present use along the Gulf Coast area are zinc and aluminum. Taking zinc first, which is sometimes called spray galvanizing when used by the metallizing process, a coating of 0.003 inch thickness provides 1½ oz of zinc per square foot of surface area and is comparable to the average galvanizing job. Zinc being strongly anodic to steel will protect cathodically large voids resulting from physical damage to the coating and its best use is in the pH range of 8 to 12. Many objects in the production field today have been metallized for corrosion protection, especially in the off-shore installations on the Gulf Coast. Wellhead assemblies, separators, storage tanks, wellguards, surface casing, and many other items too numerous to mention, have been sprayed with this method. Some of these installations have been in service since 1948, and still have many years of protective coating left on the surface for protection. For maximum protection a metallized surface should be sealed with an organic coating.

Sprayed aluminum has been used in the past more commonly to combat high heat corrosion on mufflers, stacks, headers and items as such. Sprayed aluminum, sealed with a silicone base aluminum paint, has in many instances given excellent protection in wet or dry service up to 1000 F. Aluminum is also being used for atmospheric and immersion service and shows through exposure tests that have been conducted by the American Welding Society Committee on Metallizing, to be far superior to zinc in many areas.

Other metals, such as lead, are being used as an abrasion resistant coating in dual and triple completion wells, where the flow of the perforation is opposite the inner tubing. Lead 3/16 inch to 1/4 inch is sprayed to the exterior of the

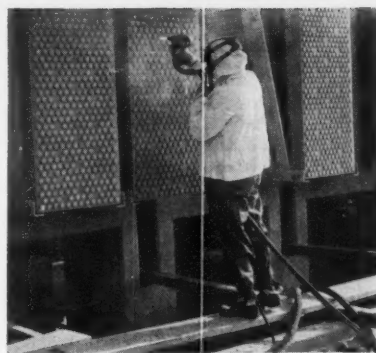


Figure 1—Lead metallizing of ends of heat exchanger bundles. Photo courtesy F. W. Gartner Co.

inner tubing. Such metals as Monel, stainless steel, molybdenum, brass, bronze and copper, have been used in rebuilding worn parts in production equipment.

Gasoline and Diesel engine crankshafts for many years have been metallized successfully, either with 420 stainless steel or 80 carbon steel. Pump plungers, pump sleeves and various types of castings, have been repaired at a fraction of cost of the original by this method.

d. Cement Lining. Cement lining for use as a protective coating in petroleum production finds its most general application in oil field tubular goods. There are applications in down hole tubular goods, but the most extensive application involves surface lines. Considering lineal footage of all diameter surface lines which have been cement lined, the great majority of installations have been connected with oil field water handling systems.

Every oilfield water flood and water disposal system requires corrosion control measures of some type. The water handling equipment is the most significant expense item in flood or disposal installations. The maintenance or replacement of this equipment may well determine the economic success or failure of a project.

Cement lining should be considered as a method of corrosion control where: (1) a reduction of the carrying capacity of the line, due to the thickness of the applied lining, is not important; (2) scaling conditions are not present; (3) internal pressures are low enough to allow the use of thin wall line pipe; (4) a type of connection other than screwed is to be used; (5) an ample supply of used tubular goods is available for lining; etc.

Cement Lining Process

Surface Preparation. As in any other lining or coating process some attention must be given to the preparation of the surface to be lined. Paraffin, oil, mill varnishes, mineral scales, rust and loose mill scales should be removed and the surface roughened in some manner to aid in producing a bond between the steel surface and cement lining. If the foreign materials listed above are not removed, they can materially reduce the actual lining thickness as applied and will obviously not aid in producing any sort of bond.

Adequate surface preparation can be accomplished by either chemical and/or mechanical cleaning.

Materials Used. There is no specification at the present time (API, ASTM, etc.) for a cement to be used in the lining of oil field tubular goods. Trial specifications have been adapted for use by some companies, however. It is recommended that the cement be a high temperature, sulfate resistant type (0.0 percent tricalcium aluminate), finely ground. The aggregate should be a finely ground siliceous type material. Some suppliers use pozzolanic materials as the aggregate. The dry mix should contain equal parts cement and aggregate. One company in doing cement lining adds to their mix a finely ground silica flour which is said to give the lining increased chemical resistance. Again, no specification is available, but it is recommended that 90-95 percent of the dry mix be able to pass through a 200 mesh sieve. The finer the grind of the mix, the more dense will be the lining and the better the service it may be expected to give.

Application. The lining itself is cast by centrifugal force. A slurry is put into the pipe, the pipe is then rotated at high speed and the cement is cast about the interior of the pipe. Excess water is then removed by elevating one end of the pipe. Uniform distribution of a uniform slurry through the length of the pipe prior to the spinning operation is very important. Such uniformity eliminates variations in lining thickness and density, a rippled, lined surface and a laminated lining. It is also very important that the lining at each end of the pipe be square to the long axis of the pipe and dense in order to make a satisfactory connection when the separate pieces are joined together at installation. Minimum lining thicknesses recommended are as follows:

Pipe O.D., Inches	Lining Thickness, Inches
2 3/8 thru 4 1/2	3/16
5 1/2 thru 6 3/8	1/4
8 5/8 and larger	3/8

All cement lined pipe should be steam-cured for at least 24 hours after application of the lining, and kept moist thereafter until installation to prevent weathering damage to the lining. If possible, the lining application should be scheduled shortly before anticipated installation.

Installation. Cement lined tubular goods can be furnished for use with any type readily available connection—flanged, welded, groove type, threaded and coupled. The most general usage is in the welded and grooved type connections. Care must be taken during the movement of cement lined pipe in order to prevent damage to the lining. In joining welded connections, asbestos gaskets, epoxy cements and Thiokol rubber have been used.

Advantages of Cement Lining

1. Initial cost lower than baked-on, or air-dried coatings.
2. Rough, used pipe or welded line

pipe unsuitable for plastic coating can be successfully cement-lined.

3. Can be successfully installed where internal pressures demand a welded surface system, or where line sizes are such that threaded and coupled connections or grooved connections are neither available nor practicable.

Disadvantages of Cement Lining

1. Reduced internal diameter of the tube.
2. Acids used to remove scale may attack the lining.
3. Costs money to transport due to weight of lining.
4. Lining more subject to damage in transportation, storage and installation than plastic coatings.
5. Does not lend itself readily to application where threaded and coupled connections are used unless special precautions are taken to protect the coupling.
6. Extreme care required with any type connection to maintain continuity of the lining during installation.

Surface Preparation

The Field Superintendent and the Corrosion Engineer are constantly faced with the problem of surface preparation. The questions are how to do it and how much of it to do. The Committee cannot sensibly attempt to answer these questions due to the many problems which exist.

The answers to the questions "how and how much surface preparation," can and should be made available by the coating manufacturer. The manufacturer of protective coatings knows exactly what type of surface preparation will give the greatest life and best results with the materials he sells.

The Committee's advice to the Corrosion Engineer is that he treat the paint manufacturer the same as his physician. He should not buy his services unless he intends to follow the advice given. The instructions are there for all to abide by. Should the instructions prove to be erroneous through field testing, a change may be necessary. This is how the doctor is treated.

Surface Preparation (General)

The preparation of metal or other surfaces to receive the protective paint or coating is usually referred to as "Surface Preparation." As this terminology is not specific in any sense it must be further clarified in the work specifications. Surface preparation may range from dusting or blowing the loose dirt from the surface to the complete removal of all materials foreign to the surface to be coated. An example of the latter is white sandblasting with a follow up vacuum cleaning job. Depending on climatic and geographical areas as well as environmental situations with the particular coatings to be used, surface preparation is usually accomplished with one or more of the following methods.

Surface Preparation Methods

a. Solvent Cleaning. Dust, light oil, fall-out contamination etc., can some-

times be removed to the satisfaction of the owner and coating manufacturer, with the use of solvents, chemical detergent mixtures etc. When this system is used, hand cleaning with rega, steam cleaning equipment, or water blast machines are normally required to handle the cleaning agents. This method is sometimes satisfactory and, if so, it is economical.

b. Hand Tool Cleaning. As the name implies, such tools as scrapers, wire brushes, chipping hammers etc., are used to remove old paint, rust scale, and weld spatter from the surface to be coated. This system is slow and costly and is usually resorted to only where the area to be cleaned is very limited. It is seldom used in connection with high grade coatings or large projects.

c. Pneumatic and Electric Tool Cleaning. This is an automated hand tool cleaning operation where more speed and therefore less cost is involved. Power wire brushes, discs, chipping hammers, scalers etc., are powered either by air or electricity. Normally the air tools are used in field work and electric tools in shop work. Many maintenance or medium size jobs are accomplished in this manner. It is not recommended where the surface to be cleaned is pitted or where the surface to be treated will be coated with high grade coatings. These tools as with hand tools will not remove rust from pits and will also leave a smooth rather than an etched surface required to give a good anchor for new coatings.

d. Flame Cleaning. The use of heat and flame produced by burning a petroleum product is an old and sometimes still used method of removing certain materials before painting. In this method a unit usually called a pre-heating machine is used to literally burn off old paint, heavy deposits of oil and grease. Quite often the difference in coefficient of expansion between mill scale and steel will cause the former to pop off when heat is applied. Many factors have to be taken into consideration when using this system. In no case will the metal so prepared be suitable for receiving high grade coatings without some other follow-up cleaning system being employed. This method is still used occasionally in the maritime field in cleaning decks on ships before repainting. When this method is used, it is also the practice to use scrapers following the heat, and to apply the paints used while the metal is still warm.

e. Pickling. During the production of ferrous metals, such as steel, oxide films form on the surface of the steel as it is processed. In large fabricating shops, this "mill scale" is removed by a pickling process, using aqueous solutions of sulfuric, hydrochloric, phosphoric, nitric or hydrofluoric acid, depending on the nature of the oxide and analysis of the metal being pickled. The removal of these oxides, and the deposition of a thin, passive film on the surface greatly increases the life of the subsequent protective coating.

f. Abrasive Blast Cleaning: General. Abrasive blast cleaning is recognized as not only the best, but the most economical method of cleaning metal before coating or before recoating as in the case of old metal. This method of cleaning is usually thought of as sandblasting which is not always correct, due to the many abrasives used, such as metal abrasives, synthetics, agricultural and many other materials designed for various types of cleaning. Many types of equipment are also used including pressure, suction, vacuum and centrifugal wheel machines. Each abrasive and each type of equipment has a place in industry, but many persons will continue to call the operation "Sandblasting."

g. Sandblasting Wet. When an air, liquid, and abrasive mixture is used in cleaning it may be referred to by many names (mostly trade names), but basically all are under the heading of wet blasting operations. The principal advantage of wet blasting is the control of dust when silica sand is used as an abrasive in pressure blasting machines. In addition to this it is also possible to use very fine abrasives in the 100 to 5000 mesh range in liquid blasting equipment. With such fine abrasives contained in liquid, finishes approaching a polished finish can be obtained. Such surfaces are required on impeller blades or other equipment and machinery that have a critical weight and moment factor. Disadvantages of wet blasting are: (1) the inability of the operator to see how clean the metal is while working, as against excellent knowledge in dry blasting operations, which accounts for slower progress and (2) the surface partially corrodes again before drying when water is the liquid used. Wet blasting was the rule rather than the exception 20 years ago, when abrasives had to be furnished by the operator in sandblasting operation. It is still used in some shipyards on bottom work. When wet blasting is done, water-soluble inhibitors, such as sodium chromate or sodium nitrite, should be added to the blast water to prevent rusting of the blasted metal. Care should be used with alkaline additives because of their effect on subsequent coatings.

h. Sandblasting Dry. Dry blast cleaning, usually referred to as "sandblasting" even though silica sand may not always be the abrasive used, is recognized as the best and fastest means of cleaning a surface. This is also the most economical cleaning system when properly accomplished; however when not properly done, costs can be completely out of proportion to the work in progress. In field type blasting operations the abrasive most commonly used is silica sand. In plant or production cleaning operations the most common abrasive used is metal shot or metal grit. Metal abrasives are made in many sizes of shot and grit from iron, steel and some alloys. The iron and steel abrasives are also heat treated to the hardness required for the work in progress.

i. Types of Blast Cleaning Equipment. The most common types of blast

cleaning equipment are either pressure or suction type. These are used in most all field work and can either be used as wet or dry blasting machines. There is also manufactured a combination vacuum pressure machine which recirculates the metal abrasive used without the common dust problem. This equipment has limited use in field applications, due primarily to its relatively slow cleaning rate as compared with pressure machines. Also available to industry is the centrifugal wheel type machine, which uses steel shot or grit for an abrasive. This equipment is very economical to operate and is used by steel mills, pipe plants and all sorts of foundry and process finishing operations. Centrifugal wheel machines are not used in field type cleaning due to several factors including cost, but mostly due to their inability to change over from one type of work to another rapidly (such as from flat metal to pipe etc.).

j. Hydraulic Cleaning. As pumps were designed before blast cleaning equipment and water is always locally available, one of the oldest methods of removing loose paint, dirt and rust scale, is high pressure water blasting. This system is used by the maritime industry and in many industrial applications where the environment prohibits the use of any abrasive in the blasting stream. Advantages for some work lie in the ability to remove some materials without dust, or hazards that are associated with dust. Disadvantages are that not all detrimental contaminations will be removed from the surface, such as pit rust and tightly adhering mill scale. And of course, no surface etch will be produced.

k. Miscellaneous Cleaning Systems. There are other types of cleaning equipment, but none of such tried and proven ability as to merit discussion at this time.

Surface Treatments, Sealers and Primers

Surface Treatments

The term "surface treatment" as usually used in connection with maintenance painting refers to those materials which are applied to a bare metal surface in order to: (1) obtain better adhesion from the paint system, and/or (2) to passivate the steel surface, giving added resistance to undercreep at points where the paint film may become broken. Surface treatments add very little in the way of film thickness to a paint system, and should not be considered a coat of paint.

The best known example of surface treatment is that given to automobile bodies at the factory before painting. This consists of a thin film of a phosphate (such as zinc, manganese, and iron) applied by dipping the body into a vat of hot phosphatizing solution, followed by neutralizing and rinsing. The phosphate solutions applied cold in the field can never do as good a job as the hot-applied treatment. They are used, however, to some extent in maintenance painting, particularly when painting galvanized steel or aluminum.

The vinyl wash primer is a type of

phosphatizing surface treatment. It is essential to use wash primer with certain types of vinyl finish coats—otherwise adherence will be almost zero.

Another type of treatment which is being used to give added life to a paint system is the penetrating oil. This is a surface-active material which is applied to a poorly cleaned surface to assist the primer in wetting the rust. The oil is applied, left for a short time, then painted over with the primer. This enables hard-drying primers to be used, yet gives them the good wetting properties of the old type, slow-drying linseed oil primers to poorly prepared surfaces. A rusty surface should never be painted over where it is possible to remove the rust. However, there are many cases where because of poor design of equipment, it is impossible to get cleaning tools into crevices. Examples of this are around bolt heads and where channels and angles have been placed back to back, then skip-welded. Penetrating oils should be used only under oleoresinous, alkyd, and certain types of phenolic primers.

Sealers

Sealers are used as a first coat over surfaces where the primer would give excess penetration (such as on new wood) or where the primer would dissolve the surface and cause bleeding (such as over asphalt and coal tar surfaces). Examples of sealers are the limed oil first-coaters for wood, the water emulsion paints, the alcohol-soluble resins, and leafing aluminum paints.

Primers

Primers are used for the same purpose as some of the surface treatments. They help the finish coats to adhere to the surface and they prevent undercreep of rust where there are breaks in the coating system. In addition, they add some film thickness to the system. They prevent undercreep by inhibiting the steel surface. Their inhibitive properties are obtained by the use of inhibitive pigments such as red lead, zinc chromate, lead chromate, zinc dust, and iron oxide. Of these pigments, iron oxide is the poorest (also cheapest), and red lead is probably the best under most field conditions. However, some iron oxide added to a good red lead primer gives the primer additional resistance to weathering when the primed steel is to lie around in the field for several months before receiving finish coats.

Most shop coat primers are low price, low quality iron oxide primers. It is better to order equipment un-primed, then do a good priming job in the field, or to specify that a good primer be applied in the shop than it is to purchase the equipment with a primer of unknown quality. A paint system can be no better than the surface preparation and the primer.

Application Methods

Brush

Proper brush application of paint depends on correct handling. The material should be transferred to the surface with

the brush, then spread carefully to assure a uniform film on the entire surface. Brush marks leave thin spots and should be avoided. Fast-drying synthetic vehicles permit very little brushing and cross lapping, so they should be applied, spread rapidly and then left undisturbed.

Synthetic bristles such as nylon are satisfactory, but are sometimes affected by paints with strong solvents such as ketones. Oval or round brushes are good for rough surfaces or rivet heads, but flat brushes are usually used on smooth or flat surfaces. Brushes wider than 4 or 5 inches are seldom used for painting steel.

Brush priming is generally considered to be better than roller or spray application on rough, pitted or poorly cleaned surfaces. Better surface wetting is obtained and there is less chance of the paint bridging over cracks or pits. Subsequent coats rolled or sprayed are generally satisfactory over these surfaces.

Roller

Roller application is faster than brushing, particularly on large flat surfaces. A smooth uniform film can be applied with proper technique. Corners and irregular shapes are best painted with brush or spray. Priming with roller is not recommended on rough, pitted or poorly cleaned surfaces and fast drying synthetics are difficult to spread into a uniform film. There are also some coatings which are absolutely impossible to apply by roller.

Many different types and sizes of rollers are made for various uses, including painting of pipe and wire fences. Long handles make many jobs easier, but rollers wider than 12 inches are too difficult to use to be very practical.

Conventional Spray

Spray painting offers a rapid method of paint application, particularly on large flat surfaces such as storage tanks. With proper technique paint may be applied very uniformly over the surface. Most spray guns can be equipped with a choice of nozzles to handle different materials and a way to vary the fan size. The spray gun manufacturer should be consulted concerning proper nozzles for various types of paints and coatings. Thinning the paint is usually necessary but should be held to a minimum.

The spray gun should be held perpendicular to the surface being painted, and about 6 or 8 inches away. The gun is passed across the surface in a uniform sweeping motion, overlapping the previous pass 50 percent. The gun must be in motion before the trigger is pulled to avoid runs or sags. It is important to have spray equipment that provides for fluid and atomizing air pressure regulation and to make sure that the equipment is always thoroughly clean.

Airless Spray

Airless spray has several advantages over conventional spray. The material is delivered to the gun at a very high pressure and is atomized at the tip without the use of air. This reduces overspray, thereby reducing material loss into the

surrounding air. Less thinners are required which allows for a higher build of material and generally with fewer pin holes in the film. Airless spray is much better than conventional spray for painting edges and corners. The amount of paint that is delivered is determined by the size tip that is used.

All paints are not suitable for use in airless spray equipment, but manufacturers are changing many formulations to adapt them to this use.

Hot Spray

There are several types of paint heaters on the market. With these units the viscosity of the paint is reduced to spraying consistency by use of heat rather than by the addition of thinner to the paint. They require a source of electric current. Some units are recirculating, and some are of the once-through type.

Advantages of hot spray application are:

- (1). Higher solids films can be deposited on a surface, resulting in less shrinkage and better build.
- (2). Variation in paint viscosity due to variations in atmospheric temperature are eliminated.
- (3). Because of better build, the desired film thickness can be obtained in fewer coats, resulting in lower labor costs.
- (4). Blushing is less likely to occur, since the paint reaches the surface at slightly above atmospheric temperature.
- (5). Lower atomization pressures can be used, resulting in less overspray and loss of material.

Disadvantages are:

- (1). A painter can often obtain the desired film thickness in one coat, and it is very difficult to apply one coat of any coating material pinhole-free.
- (2). An inexperienced operator can frequently produce a porous film by holding the spray gun too far from the surface or by using a product containing very fast solvents which has been designed for conventional spraying. The solvent leaves the paint particles too rapidly, resulting in dry balls of paint deposited on the surface.
- (3). Excessively thick films can be deposited, resulting in wrinkling and solvent entrapment in the film.
- (4). Hot spray application can be used only where the paint heater and its power source can accompany the painter. It is not suitable for tower and bridge work.

Inspection Methods

The primary function of an inspector on a coating job is to see that the work being done meets the specifications. A secondary function is to assist in arranging other work or conditions so that a painting crew can work with maximum efficiency and minimum damage to finished coatings.

The job specifications should outline and define the duties and authority of the inspector, the time and place the inspection will be made (this primarily for independent inspection services), and

the name or type of all quality control or measuring devices to be used by the inspector. With all this information in writing, the inspector must have know-how, and be dependable, accurate, and thorough. He must be able to keep the job, the quality, and acceptance on course. He must be a bookkeeper, knowing what records to keep and keeping them. He must be in a position to prove and defend every point questioned. Authority alone does not give or get cooperation in the field.

A successful coating system must have:

- (1). Adequate film thickness for long term durability.
- (2). Coating continuity (freedom from holes).
- (3). Good adherence, or bond.

There exists instruments which an inspector in the field can use to measure the first two. There is no non-destructive test for measuring coating adherence. Adherence should have been checked on panels for the paint system specified before the specifications were written.

Film Thickness Measurement

Most film thickness measurements in this country are expressed in "mils," or thousandths of an inch.

a. Wet Film Gauges. If the solids by volume content of a paint is known, the dry film thickness which will result from a coat of paint can be determined by measuring the wet film thickness. For example, a paint containing 50 percent solids by volume shrinks to half its wet thickness as it dries, since the other 50 percent is solvent which evaporates into the air. With this paint, 2 mils wet will yield 1 mil dry. With a paint of 25 percent solids, 2 mils wet will yield 1/2 mil dry.

Wet film measurements are used primarily as a guide during application. The wet film to dry film calculation is not entirely true in the field, particularly with coatings such as vinyls, which contain fast solvents. Some of the solvent is lost as the paint is atomized in a spray gun, and the paint particles hitting the surface may be of much higher solids-by-volume content than is the paint as it comes in the can. Also any thinning done in the field must be taken into consideration when making wet to dry conversion.

All wet film gauges operate on the same principle. Part of the gauge is pushed through the wet film, and the thickness is determined by how far the paint goes up on comb-like teeth, an eccentric wheel, or a calibrated spherical section. The comb type wet film gauge is most used in the oil field. This gauge (Figure 2) has two outer legs of equal length; the inner legs get progressively shorter. This type of gauge is pressed into the wet film in a position perpendicular to the surface, then removed and examined to see which is the last of the teeth (going up the scale) which has any paint showing on the end of it. A wet film reading should be taken immediately after a spray pass is made. The longer the time lapse between the spray pass and the taking of the measurement, the more the solvent is going to leave the



Figure 2—Comb type wet film thickness gauge. Photo courtesy Nordson Corp.

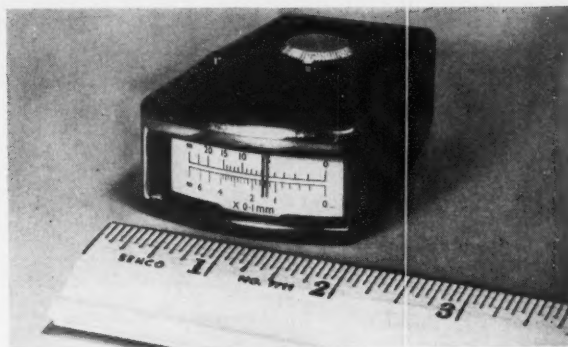


Figure 3—Elcometer dry film thickness gauge. Photo courtesy Gardner Lab., Inc.

film and the less accurate will be the measurement.

b. Dry Film Gauges. There are several different kinds of dry film gauges on the market; two most widely used in the oil field are the Elcometer (Figure 3) and the Tinsley Gauge (Figure 4). Both are based on a magnetic principle. With the Elcometer, a button is pushed, and the film thickness is read from the deflection of a hand on a scale. With the Tinsley Gauge, a small magnet pulls out a calibrated spring; the film thickness is indicated by how far the magnet pulls the spring out before it lets go of the surface. Another type which is being used in many chemical plants on the Gulf Coast is the "Mikrotest" (Figure 5). Before taking measurements with any of these gauges, they should be checked for zero reading on a piece of bare steel of the same type and with the same surface preparation as the steel being painted. These gauges work only on steel or iron. They are influenced to some extent by the presence of iron oxide pigments in paint films, the iron oxide causing the reading to be lower than the actual film thickness.

In the event of a disagreement between owner and contractor over actual film thickness when different instruments show different apparent thicknesses, a small piece of the coating system can be removed down to bare metal with a razor blade and measured with a micrometer.

Color Break

Inspection of the progress and quality of a painting job is made much easier if there is a good color break between each coat in a system. A good color break also enables a painter to tell where he has painted with a certain coat of paint and where he has not as the system progresses. The greater the contrast between the colors of two adjacent coats, the less will be the likelihood of coats of paint being left out of the system.

In a conventional type paint system, lamp black in oil is usually used for tinting one of the coats of primer, and prussian blue is frequently used for tinting one of the coats of tank white or aluminum to give a color break. In the event that these are not available, black or blue enamel of the type found in all oil field supply stores can be used for tinting. Care must be used that tinting

is not overdone on a next-to-last coat of tank white, or the final coat will not give complete hiding. A little bit of blue goes a long way in tinting a white.

Holiday Detectors

Holes in a coating system are detected after the paint has dried by means of what is known as a "holiday detector" or jeep. An electrical holiday detector is a device which locates areas or points on a coated metal surface where there is a very great difference in electrical resistance between an exploring electrode on the coated surface and the underlying metal. The fact that most corrosion resistant coatings are highly resistant to a flow of electrical current makes this method of test quite practical.

A practical holiday detector consists of an electrical energy source such as a battery or high voltage coil, an exploring electrode and a connection from the energy source to the coated metal. The device should be equipped with a visual and/or audible alarm to signal current flow through the apparatus.

In general, two types of detectors are in current use: the so called "spark" detector which is used to apply high voltage to the surface of thick coatings such as coal tar or asphalt and the so called "non-destructive" detector (Figure 6) which is used to inspect relatively thin coatings such as epoxy or vinyl base type materials. With the spark detectors, high voltage (8,000 to 15,000 volts) is applied to the coated surfaces with an exploring electrode consisting of a wire brush, electrically conductive silicone, or coil spring. If a holiday or very thin section is passed over by the electrode, a spark will jump from the electrode through the air gap to the metal. With the non-destructive detector, a source of less than 75 volts is used applied to the coating with an electrode consisting of a cellulose sponge dampened with an electrically conductive liquid such as tap water. The electrode pushes a film of liquid over the surface and when a holiday is encountered, current will flow through the liquid to the metal. In both type detectors, audio or visual indicators are used to signal a defect.

An electrical holiday detector should be used at the time the coating is applied. The holiday detector should never be used to evaluate the quality or useful-

ness of a type of coating but should be used only as an aid in the application of the coating to insure film continuity. When the detector is used at the time of application, holiday can be readily located and repaired. The detector not only locates holidays but it enables the applicator to develop techniques of better application.

Although the electrical holiday detector is an effective inspection device, some judgment is required in its use. To make the device effective, an indicator such as a bell or light is used to indicate current flow. This indicator is usually actuated from the amount of current flowing from the electrode through the coating or through a holiday to the metal surface. If a coating is applied which does have electrical conductance (low resistance), then current may flow in sufficient quantity to actuate the alarm signal at any point on the coating surface and the detector then cannot be used. It is well then to know in advance the approximate electrical resistance of the material being tested. Prior to the use of a holiday detector for inspecting a coated surface, one should always break the coating at some point and check the operation of the detector by passing the electrode over a point which is known to be faulty. When working with spark detectors, the operator or buyers should be aware that excessively high voltage of application will stress some coating materials to failure and the device then would be destroying areas of good coating which otherwise would have been satisfactory.

Coverage Rates

A gallon of anything will cover 1600 square feet to a depth of 1 mil (or thousandth of an inch) wet. Therefore, it is said that a gallon contains 1600 wet mil-square-feet. The dry mil-square-feet left after the solvents evaporate from the paint is determined by the solids content (by volume) of the paint. For example, a paint which is 50 percent solids by volume would contain 800 dry-mil-sq. ft. per gallon and would cover 800 sq. ft. 1 mil thick, 400 sq. ft. 2 mils thick, or 100 sq. ft. 8 mils thick. Set up as a formula, the calculation of coverage becomes:

$$\frac{1600}{\text{dry mils}} \times \frac{\% \text{ solids by volume}}{100} = \text{sq. ft. per gallon}$$

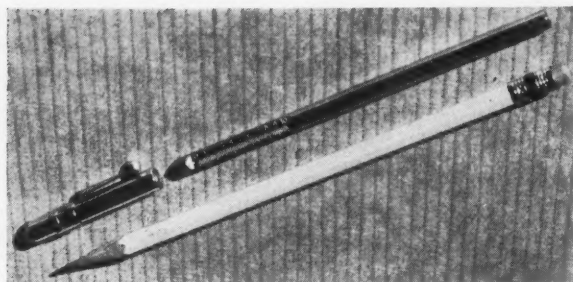


Figure 4—BSA/Tinsley pocket dry film thickness gauge. Photo courtesy Union Screen Plate Co.



Figure 5—Mikrotest dry film thickness gauge. Photo courtesy Nordson Corp.

TABLE 2—Weathering of Tank White Films

Pigment Ratio	Lost, Mills	Loss Per Year, Mills	Calculated Time for 1 mil loss, Yrs.
100 percent free chalking	2.2	0.49	2
80 percent free chalking	0.6	0.13	7.7
30 percent chalk resistant	0.4	0.09	11
60 percent free chalking			
40 percent chalk resistant			

This, of course is the theoretical coverage rate, which means the rate on a smooth piece of metal, no anchor pattern to fill up, and no wind to blow the paint away. Practical values run from 50 percent to 90 percent of the theoretical, depending on application conditions and the type of surface being painted.

The formula can be rearranged to give the expected dry film thickness when the paint is to be applied at a specified coverage rate:

$$\frac{1600}{\text{sq. ft. per gal.}} \times \frac{\% \text{ solids by volume}}{100} = \text{dry mils}$$

If the price of the paint is known, along with the solids content, the actual cost of the paint on a dry basis can be calculated:

$$\frac{\text{Price in cents per gallon}}{1600} \times \frac{100}{\% \text{ solids by vol.}} = \text{\$ per mil sq. ft., dry}$$

Typical range of solids by volume in some various types of paints are:

Aluminum	28—35%
Alkyd enamels and primers	35—55%
Oil base paints and primers	50—80%
Chlorinated rubber	35—40%
Vinyls	20—30%
Catalyzed epoxies	35—45%
Coal tar epoxies	65—85%

Check with the manufacturer of any particular paint for exact solids content.

Painting for Reflection

Tanks holding high-gravity crudes or light products should have top coats of high reflectance. White has the highest reflectance, followed by aluminum and the pastels. Tank whites are formulated to give varying chalking rates. In a dirty area, a rapid chalking white is necessary to keep the tanks clean. On the other hand, in a clean area, a slow chalking white is adequate to maintain the whiteness of the tanks. The slowest chalking

rate which will still maintain the desired degree of whiteness of the tanks is the most economical one to use, since chalking is certainly a wearing away of the paint film.

Estimates of the rate of weathering of tank white films are usually quite a bit in excess of what actually occurs. It is of interest to note some recent data on weathering of tank white films (see Table 2). The whites on test consisted of alkyd vehicle with varying ratios of free-chalking and chalk-resisting titanium dioxide pigment. Panels were exposed 4½ years at a 45 degree angle facing south at Metuchen, New Jersey.

These rates will of course be somewhat higher in the South and Southwest, however they would not be expected to be more than twice the above values. In very hot humid areas, such as along the Gulf Coast, only mildew-resistant tank whites should be used, and these should have proven performance locally.

Special Environments

Hot Surfaces

Paints which give excellent service when applied to surfaces subject to temperatures under 200 F perform with decreasing satisfaction as the temperature is elevated. Surfaces with skin temperatures above 200 F require heat resistant paints to delay the destructive action caused by elevated temperatures. These coatings, while effective within the temperature ranges recommended, have shorter protective life than coatings used at normal temperatures. The several types of heat resisting coatings which are in general usage are:

- (1). Alkyd aluminums
- (2). Bituminous blacks
- (3). Modified silicones
- (4). Straight silicones
- (5). Zinc dust grays
- (6). Aluminum metallizing
- (7). Zinc inorganics

For recommendations on any hot surface, the paint manufacturer should always be consulted.

The straight silicones are most effective when pigmented with aluminum. These are expensive coatings when compared with conventional paints or with other types of heat-resistant paints. It is a waste of money to purchase these fine materials unless a first-class surface preparation is done prior to their application. For best results, the silicones should be applied in two coats, with the equipment being heated to 400 F for at least 30 minutes after each coat is applied.

Two factors are of primary importance in the application of coatings for high temperature service: (a) surface preparation, and (b) the temperature of the surface at the time the paint is applied. Where sandblasting is not practicable or permitted, all scale, rust, etc., which may loosen with subsequent temperature changes must be removed by other means, such as the use of a power-driven disk sander. The temperature of the surface being painted should be at ambient or only slightly above. It does no good to "fry the paint" on the surface. Two coats are usually more satisfactory than one coat. Film thickness should not exceed 1½ mils dry per coat.

It is advantageous if the temperature of the equipment is very slowly brought up to operating range immediately after application of the final coat. This is especially true in the use of silicones.

Difficulty has been generally encountered in service where temperatures are intermittent. To date, the aluminum pigmented silicones appear to perform the best of all coatings in this service, except perhaps a good metallizing job. However, work is being done with and observations being made on the use of zinc inorganic coatings for such service, up to a maximum temperature of 600 F.

Above the temperature limit of the silicones, sprayed metal coatings (metallizing) are the only coatings which are both effective and can be applied in the field. With these coatings, there is no compromise on surface preparation; it must be a white metal blast.

Most people tend to overestimate the temperature of hot surfaces. There are several ways of determining the temperature:

- (1). **Sticks.** These resemble crayons. They come in a series of melting points, in 50 degree steps. The stick is placed against the metal surface. If it melts, the stick with the next higher designation is

tried, and so on until one does not melt. This will fix the temperature to within probably 25 degrees, which is close enough for selecting a heat resistant coating.

(2). **Pyrometer.** This instrument is the most accurate (and most expensive) of the three measuring devices. Its accuracy is far greater than needed for selection of most heat resistant coatings. The sensing head is placed against the surface whose temperature is to be measured, and the temperature is read from the dial on the box (Figure 7).

(3). **Thermometer.** This type thermometer is held to the steel surface by means of a small magnet (Figure 8). It is pocket-size, of sufficient accuracy for coating selection, and it sells for under \$10.

It should be emphasized that conventional primers should never be used with heat resistant paints. The primers will decompose, blister, and fall off, bringing the heat resistant paint with them.

Sour Crude Storage Tanks

(a) **Surface Preparation.** For immersed service conditions of the severity typical of crude oil-salt water services, sandblasting to white metal, in accordance with Steel Structures Painting Council Surface Preparation Specification No. 5—Blast Cleaning to White Metal, is recommended. Blasting pressures of a minimum of 90 PSI at the nozzle should be maintained in order to provide optimum cleaning qualities. The metal profile of 1.0-1.5 mils is suggested to receive the vinyl or epoxy systems recommended below.

After general surface preparation and sand removal has been completed, all surfaces should be blown down with air to remove residual sandblast dust accumulations.

b. Coating Systems.

(1) **Vinyl System.** This is a multiple coat, resistant vinyl system. Total dry film thickness for this system should be a minimum of 5.0 mils. Satisfactory service for this type of properly applied system now stands at an average of 7-10 years.

For new, or unerected bolted tanks, it is recommended that the first three coats consisting of one or more prime coats and a body coat, be applied and inspected for holidays prior to erection. After erection, holidays and mechanical damage should be repaired with spot coats of a suitable finish, followed by the balance of the required number of finish coats.

Where welded tanks or previously erected tanks are involved, all coats should be applied on location with attention being given to holiday inspection at the end of the third coat.

(2) **Epoxy System.** The multiple coat catalyzed epoxy system should consist of a suitable inhibitive primer, an intermediate coat, and a finish coat of selected color. Total dry film thickness for this system should not fall below 6.0 mils. A coal tar-epoxy system is usually applied in 2 coats of 6 to 10 mils each. This

type of material is giving excellent service in both sour crude and sour brine exposures. There is a trend toward increasing use of epoxy coatings and decreasing use of vinyl coating for this service. The epoxies and coal tar-epoxies have not been in general usage for more than 4 or 5 years, but service life should be comparable to or better than that of the vinyl system.

For bolted and welded tanks, all coats of epoxy system should be applied on location with attention being given to holiday inspection after the second coat.

c. **Weather Considerations.** Vinyl coating system should not be applied when ambient temperatures and steel surfaces are below 40 F. Epoxy systems should not be applied when ambient temperature conditions and steel surfaces are below 50 F. Drying mechanisms involved with catalyzed epoxy coatings will be greatly reduced at temperatures below 50 F. Curing time can be reduced by use of warm air blowers. All systems should be applied in clear, dry weather conditions. Maximum allowable humidity is 85 percent.

d. **Special Considerations.** (1) **Deck Surfaces.** Floors and deck surfaces of stock tanks should be closely inspected to insure minimum film thicknesses and freedom from holidays. It may be desirable to apply an abrasion resistant overcoat to vinyl systems where heavy sand and sludge accumulations require frequent tank cleaning operations.

Hot applied coal tar tank bottoms, cutback coal tar mastic bottoms, and concrete bottoms have given 15-20 years service. New processes using newer synthetic resins sometimes laminated with glass fiber also appear promising for protection of tank bottoms.

(2) **Vapor Space Areas.** Attention should be given to strip coating all bolt rows, channel members, etc. with the brush applied additional coat of finish after erection.

Well Tubing

Most coatings being used today for the interior of well tubing are of the baked-on variety. These so named baked-on coatings are to be defined as those coatings which require temperatures of 300 F or more to effect curing. This is in contrast to forced or accelerated curing of "air-dry" or chemically converted coatings. The forced curing methods generally are produced at temperatures of 125-150 F for 15-30 minute periods and serve primarily to speed up solvent removal. In baked-on applications the heat speeds up solvent removal plus effecting cross linkage of molecules, commonly referred to as polymerization.

The coatings which will be described fall into the baked-on coatings group, and described more fully in the ensuing paragraphs, are generally considered as those composed primarily of phenolic, epoxy or polyurethane resins and may vary widely due to resin ratio. The phenolics are generally referred to as the "straight phenolics," the polyurethanes generally are a "urethane" while the

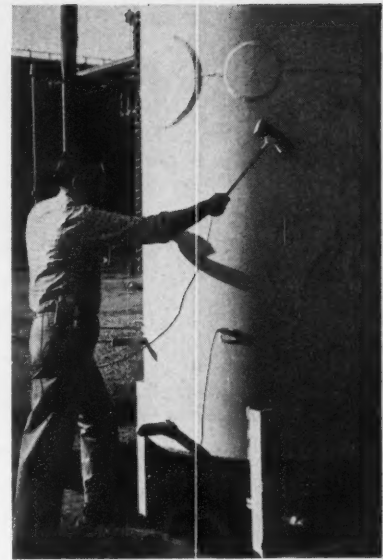


Figure 6—Checking coating for pinholes using low voltage holiday detector. Photo courtesy Tinker & Raor.

epoxy coatings often are referred to as an "epoxy, an epoxy-phenolic, a modified epoxy, a phenolic-epoxy or a modified phenolic." While each description is generally true it must be remembered that resin-ratio in each of these coatings will vary according to the manufacturer and designation will normally be made at the suppliers discrimination.

a. **Phenol-Formaldehyde.** The phenol-formaldehyde coatings commonly referred to as "straight phenolics," sold under various trade names are the oldest of the baked-on coatings now in use in the oil country. The resins are non-oil soluble and when properly cured, show outstanding physical and chemical resistance and are notable in that they do not soften when subjected to elevated temperatures. At high temperatures, they will char but will never soften. These phenolic coatings are odorless, tasteless and non-toxic, and are frequently used in lining containers for edible foods and drinks.

These coatings possess the greatest known per mil thickness resistance to water, gas or oil permeation when subjected to conditions of elevated temperatures and pressures. The extremes of pressures normally recommended are of the 10-12,000 psi range and for temperatures the normal acceptable range is generally considered to be 300 F. Mil thickness for applied coatings is generally in the range of 5-7 mils when used to control corrosion.

These coatings may be used satisfactorily in all types of sweet oil and gas production, water wells, water flood systems and salt water disposal systems. Caution must be used however in sour production, as performance in H_2S environments is inconsistent. In sweet wells CO_2 contents as high as 35 percent have been encountered with no adverse effect on coatings after five years.

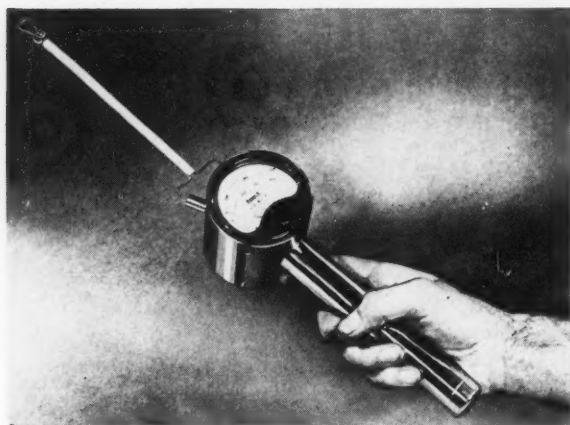


Figure 7—Surface temperature pyrometer. Photo courtesy Pacific Transducer Corp.

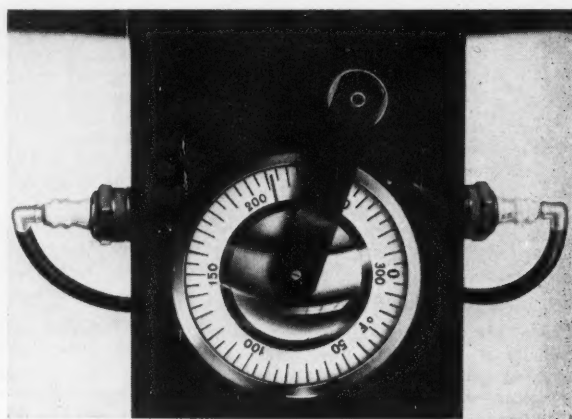


Figure 8—Measuring jacket temperature with pocket-type surface temperature thermometer. Photo courtesy Pacific Transducer Corp.

Normal acidizing with 15 percent HCl (wash acid) has no adverse effect on these coatings when exposure times are less than 6 hours and temperatures do not exceed some 275 F and 8,000 psi. Mud acid (15 percent HCl and 3 percent HF) affects all phenolic coatings to some degree if the temperature is high enough and contact time is long enough. A contact time of 4 hours at temperatures below 200 F is the maximum recommended with mud acid. Contact with super mud acid (15 percent HCl and 6 percent HF) should be avoided whenever possible.

Drilling muds may be satisfactorily used when the pH of the drilling mud does not exceed 12.0. Above this pH other available coating systems offer more satisfactory resistance.

Damage to these coatings, which are flexible in that they will withstand flexing to the elastic limit of the steel when applied in proper thickness, may result from gouging, the cutting action of frayed wire line cables, sharp edges of wire line tools or from misalignment when stabbing at installation. Erosion may also occur due to high flow rates, from sand carried in the flow stream or from the jetting action of gases introduced through gas lift valves.

Field repairs for damaged coated areas are impractical. Temporary "patching" may be done with "air-dry" or catalyst cured materials but service conditions must be considered before these are used.

b. Epoxy-Phenolic; Phenolic-Epoxy, Modified; or Modified Phenolics. This series of coatings dates from about 1952 and has been somewhat confusing to the user due to various nomenclatures assigned to them. Manufacturers have generally referred to their specific coating by that designation which most closely suited their interests.

These coatings consist primarily of the ingredients of a methylated phenolic and epoxy resins plus pigments, solvents and other additives, according to the desires of the formulator. One of the characteristics of these coatings is that they are somewhat thermoplastic—that is they

will soften somewhat when subjected to heat.

Applications made to oil country tubular goods have displayed good resistance to water, oil and gas permeation when temperatures are held to a maximum of 250 F and pressures are limited to 6-8,000 psi. Some applicators recommend usage where these conditions are exceeded and satisfactory installations have been made. Considerable thought should be expended before exposing these materials to conditions of extreme limits. Normal thickness to which these materials are applied is 5-7 mils when used for corrosion control.

Satisfactory services for these coatings are in oil and gas production, salt water disposal wells and water flooding. These coatings have been successful in wells producing high percentages of carbon dioxide but like the phenolics, performance in hydrogen sulfide environments is inconsistent.

When acidizing either with hydrochloric acid or with hydrofluoric acid, and within the temperatures and pressure ranges outlined as limits, performance of these coatings will be something less than that as outlined for the phenolic series.

Drilling muds of the high alkalinity range, pH 11.0 plus, have no effect upon these coatings when used within the prescribed pressure and temperature ranges.

Another valuable asset of these coatings is a high degree of flexibility and excellent resistance to mechanical damage from "down hole" tools. The possibility of damage during installation of pipe, notably lip damage occasioned by stabbing, is less than that normally expected from the phenolics. Here again erosion due to high flow rates, entrained sand and jet action may occur. Damaged coating may not be restored to its original standard by field repairs but temporary repairs may be made by patching with "air-dried" or chemically cured materials.

c. Overlay Systems. This type system is most frequently used or requested when properties of both the phenol-formaldehyde and epoxy-phenolic coat-

ings are desired. The normal application consists of the application of the phenolic in 3-5 mil thickness and then overlaying this with a 2-3 mil thickness of epoxy-phenolic.

In this type application, each of the coatings assume and maintain their individual characteristics of chemical and physical properties and no changes will be evident in maximum pressure and temperature limitations. The coating retains its excellent resistance to acid attack and high temperature limitation. While the epoxy-phenolic retains its resistance to caustic (important if completing the well in a high pH drilling mud) and excellent abrasion resistant qualities. In this type system the epoxy-phenolic and phenolic are fused together in the baking process resulting in a 5-8 mil coating thickness.

d. Newer Developments. Ever increasing demands for a coating to withstand the extremes of pressure, temperatures, flow rates, chemical environments in deeping wells have resulted in the development of several new coatings. At this date, these coating systems are relatively new and the field data available are so limited that these will be only noted. Should individual wells require such a coating, valuable information may be obtained from the company's own laboratory or from the coating supplier.

Another development, in use for over two years is the baked-on polyurethane. One applicator recommends its use where conditions do not exceed 225 F and 5,000 psi.

This material has been used in water disposal wells, water flood systems, pumping wells and low pressure flowing oil wells. Flexibility permits coated pipe to be field bent for installation without affecting the coating. Also, damage from wire line tools, frayed cables, abrasive actions and other such environmental hazards is reduced, when compared to other coatings mentioned above.

Mil thickness for this coating is 5-7 mils when used for corrosion control.

e. Care of Coated Tubing. In order to get the most satisfactory service from

coated tubing, the following precautions are suggested:

1. The user should consult with the supplier before the coated tubing is run.
2. Unnecessary wire line work should be avoided with coated tubing whenever possible. If coated tubing is to be calipered, the use of special calipers designed for use in coated strings should be considered.
3. Pin end thread protectors should not be removed until string is ready for running.
4. Metal rabbits should not be run through coated tubing.
5. Coated strings should be handled with a certain degree of common sense. For example, special stabbing tools are available for running coated tubing; these should be used.
6. Metal bars or hooks should never be inserted in coated pipe.

Sucker Rods

Most coatings applied to sucker rods have been used to prevent the deposition of paraffin and in most cases have been markedly successful. In some cases they have reduced corrosion. There is a definite probability that the coating will be abraded off the rod when and where the sucker rod contacts the tubing. Such coatings are not usually recommended to control corrosion of sucker rods, unless they are used in combination with inhibitors.

Galvanized Surfaces

Galvanized iron surfaces have physical and chemical properties which differ from those of steel. Conventional metal primers, which adhere satisfactorily to steel, frequently fail by peeling when applied to galvanized iron.

Many theories have been advanced to explain the lack of adhesion of conventional primers to galvanized surfaces. It is generally agreed that the extremely smooth, spangled, oily surface of new galvanized iron, together with a flexing action, which is characteristic of the zinc coated structural sheets during changes of temperature, are the principal causes of such paint failures.

Galvanized iron requires primers which are formulated specially for this purpose. Proper surface preparation is also highly important.

a. Surface Preparation. Lubricants commonly used in the galvanizing process are deposited as a film on the surface of the sheet and prevent good adhesion of the primer. Dirt or grease should be removed before painting. Satisfactory results have been obtained by any one of the following methods.

(1) *Cleaning.* Scrub with a solution of $1\frac{1}{2}$ oz tri-sodium phosphate and $1\frac{1}{2}$ oz soap chips to each gallon of water. Synthetic detergents such as sodium metasilicate and petroleum sulfonate are also effective. In either case, a thorough rinse with clear water is necessary before painting.

Washing with naphtha or mineral spirits is effective for the removal of oil

and grease if properly carried out. Always use fresh solvent and wipe dry with a clean cloth. Do not use solvent which is contaminated with oil.

(2) *Weathering.* Allow to weather for from 3 to 6 months. During this exposure to rain, wind and sun, oily deposits are removed and the galvanized iron becomes roughened naturally, which offers a much better surface for adhesion of the primer.

(3) *Etching.* Chemical roughening by etching with vinegar or copper sulfate and acid solutions is a quicker method than natural exposure to weather. However, chemicals which have an etching action on metallic zinc leave unstable crystalline deposits which should be removed before the paint is applied. Use a stiff bristle brush followed by a rinse, or preferably a hosing, with clear water. If these deposits are not removed, the paint may peel.

b. Priming and Painting. Two types of primers for galvanized surfaces are in general use: (1) the alkyd or oleoresinous vehicles pigmented with zinc dust, and (2) the vinyl wash primers.

Either type primer can be used successfully where the finish coats are to be conventional paints or enamels. Where the finish coats are to be one of the chemical resistant coatings such as vinyl, chlorinated rubber, or epoxy, the wash primer is preferred. Wash primer can be coated over in from 30 to 60 minutes after application. But where catalyzed epoxy is to be the next coat, better results will be obtained if the wash primer is allowed at least 8 hours drying time. This allows all the phosphoric acid in the wash primer to react with the galvanizing. If wash primer is overcoated too soon with epoxy, the acid remaining in the primer reacts with the alkaline catalyst in the epoxy, and a poor bond between coats results.

Concrete

Concrete, especially new concrete, is quite alkaline; therefore oil-base paints and enamels do not work well over it unless the surface is specially prepared. Concrete should be allowed to cure thoroughly (at least 1 month) before any painting is attempted.

The emulsion paints, such as the PVA's and acrylics, which are not sensitive to alkali, have functioned well as coatings for concrete buildings, pump bases, etc. These can be used as both prime and finish coats, or they can be top coated with conventional coatings.

Vinyl, chlorinated rubber, and catalyzed epoxy coatings can be applied directly to cured, dry concrete. These do an excellent job on concrete floors. A minimum of three-coat application should be made for best results, with the first coat being thinned 25 to 50 percent to penetrate the pores and to give a good bond with succeeding coats.

Condensate or Light Products Tank Interiors

A coating for interior of condensate or light products storage tanks should have a high degree of resistance to organic

acids, oxygen, condensed water droplets, both aliphatic and aromatic hydrocarbons, and in the case of sour condensate, to permeation by hydrogen sulfide.

Two types of coatings have proven satisfactory for this service both for cone roof and floating roof tanks: catalyst cured epoxies and zinc inorganic coatings. Applied costs and expected life are approximately the same for both types of coatings in sweet service. Zinc inorganic coatings are not recommended for sour service.

In-Place Lining of Pipe Lines

It is possible to successfully apply organic linings to the interior of buried pipe lines without removing the pipe from the ground. The procedure is as follows:

In most cases after a contract has been signed to internally clean and coat a given pipe line, the producer clears the line of oil or water and checks for leaks.

Then a pressure test is applied depending on the requirements for the line, (usually, at least 100 lbs.). The contractor takes over at this time. The line has been cut at both ends and the first move is to attach "pup" joints, which serve as the leading media for cleaning materials, air, and coating.

Cleaning then begins. Specially developed cleaning tools including wire brushes, metal snakes, and other types of grippers, are attached to rubber cups which catch the air pressure, sending the cleaning tools through the line. Batches of lathe cuttings with cotton waste behind them also are frequently used.

The mechanical or abrasive cleaning is supplemented in most cases with chemicals. The latter includes detergents, alkali rinses, acid neutralizers, water in large quantities, and selected solvents such as methylethyl ketone, ethyl alcohol, etc. Inspection spools are often placed at intervals along the line to check the cleaning operation.

After the line is clean, the coating is applied. At the present time, high viscosity (heavy body, thixotropic) cold-cured epoxy formulation are used practically exclusively. These materials have a potlife of from a few hours to over 24 hours. This is the only controlling factor determining the possible length of line that can be coated at one time. Therefore, it is generally conceded that 10 miles would be the maximum that a contractor would undertake to clean and coat at this time. The coating is mixed with curing agent and introduced into the line. If it is a small gathering line, usually gravity is all that is necessary; however, on larger lines the coating is introduced with air pressure on special mixing devices.

The coating is applied utilizing special rubber coating plugs. Sometimes this operation is referred to as "squeegee"; however, the coating is actually applied under pressure and laid on the interior wall surfaces. The coating is placed between two sets of plugs which are held together by a forward and back pressure. Usually a 10 pound differential is all that is required. In this way, the "paint train" is moved through the line at a controlled

rate of speed and consequently a controlled film thickness can be applied, except for bits, collars, etc. Excess coating is removed from the line and sometimes a "wiper" plug is used to smooth out a particularly rough line where numerous pits or low areas have caused some heavy build ups. The line is then dried by blowing air through for 4-12 hours.

This type of coating job is usually done for prevention of corrosion by sour crude, fresh and salt water and various chemicals, although a slick coating such as this has also been used for paraffin mitigation. This method has also been used in the interior of gas transmission lines to decrease friction between the gas and the pipe walls.

Selecting a Painting Contractor

In selecting a painting contractor you desire to have bid your painting, a thorough check into the background of all contractors in your area should be made. By having only competent contractors on your bid list you will be assured of a quality job and performance.

Past performance is probably the best recommendation a contractor can have. With a list of their customers it is possible to check with the field engineer or purchasing agent to find how satisfactorily they performed their work. Obtain only the company name, not the names of their friends within the company.

Be sure the contractor is fully qualified for the particular job. Where he may have performed well on a tank farm job he may or may not be qualified to perform specialty cleaning or coating systems in other areas of the plant.

Proper equipment is important as well as experience. Outdated or poorly kept equipment can have a great effect on the quality of the work performed. Painting equipment is expensive and many reputable contractors are limited in the type of work they should attempt because of their limited equipment.

The financial standing of the contractor should also be considered. Often a company will have one of their jobs half completed only to find the contractor is having trouble meeting his payroll or is unable to buy additional material to complete the job.

Summary for selecting a painting contractor:

1. Check names of qualified painting contractors in your area.
2. Type of organization.
3. Can perform your type of surface preparation or application.
4. Proper equipment for job.
5. Will their financial background be sufficient to operate your job.

Typical Coating Defects and Their Causes.

Peeling

a. Contamination of the surface. The surface being coated can become contaminated by:

- (1). Moisture condensing from the air when the surface temperature is below the dew point.

(2). Oil from a compressor being deposited during sandblasting when either no separators or inadequate separators are used in the air line from the compressor to the blast pot.

(3). Deposition of salt spray in coastal areas or near cooling towers.

b. Use of incompatible materials in a system.

c. Failure to remove salts left by curing solutions used with inorganic zinc coatings.

d. Failure to add the catalyst to one or more coats in a catalyst-cured coating system. This can be detected by rubbing the back of a peeling with some of the thinner used with the coating. If the catalyst has been left out, the coating can be redissolved in its thinner.

e. Inadequate surface preparation.

Blistering

a. Painting over moisture. When the water droplets vaporize in hot weather, blisters occur in the coating.

b. Soluble salts under a coating. This causes osmosis when the coating is used in immersed service in fresh water. Such blisters will be full of liquid.

c. Solvent trap, which occurs when an excessively thick coat is applied. The coating dries on the surface while still remaining liquid underneath. The solvent, in attempting to come out of the film, pushes the surface-dried film outward.

d. Coating is permeable to gas. Severe failures of this type have occurred where vinyl coatings have been used in hydrogen sulfide service, such as on interior of cone roof tanks in sour crude service. The hydrogen sulfide penetrates the coating and reacts with the steel surface, generating hydrogen.

Alligatoring

a. Temperature of surface in the summer is above the softening point of the coating. This occurs frequently with coal tar or asphalt coatings which have been applied in thick films.

b. Partial incompatibility between coats, such as where a hard-drying alkyd finish coat has been applied over a soft-drying oil base primer.

c. Application of finish coats before primers have dried thoroughly.

Pinholing

a. Too-fast (volatile) solvents in coating material. The paint particles become dry between the time they leave the spray gun and the time they hit the surface. These particles do not flow out, or coalesce, to form a continuous film. This occurs frequently with gas drying materials such as vinyls in the summer. It can be prevented by the addition of a small amount of slower (less volatile) solvent to the paint prior to application.

b. Water in the paint due to lack of adequate separators between the compressor and the paint pot or paint pump. The water is deposited in the film along with the paint, where the water droplets evaporate and leaves pinholes.

c. Pinholes in a finished coating job have often been caused by weld spatter. When welding is to be done above a painted surface, the surface should be covered with dirt, sand, old tarpaulin, empty sand sacks, or the like.

Fish eyeing (of catalyst-cured epoxies and phenolics)

a. Water or oil (possibly from compressor) in paint or on surface being painted. This can be eliminated by use of adequate trap in air lines.

b. Improperly formulated coating material.

c. Catalyst not thoroughly dispersed in base material.

Sagging or festooning

a. Too much paint applied per coat.

b. Too much thinner added to the paint.

c. Paint as formulated has insufficient "stay put".

d. Atmospheric temperature too low for satisfactory paint application.

Chalking

All paints will chalk sooner or later in various degrees. This phenomenon is used to advantage in the self-cleaning tank white. However, excessive chalking indicates a too-rapid breakdown of the paint film and is caused by improperly formulated paint.

Blushing

This term is used for the appearance of a white film on the painted surface shortly after application. It is caused by water in paint films which have been applied during periods of excessive humidity (over 85 percent). The addition of some slower solvent to paints such as vinyls can help decrease the amount of blushing, although for best results the painting should be postponed until weather conditions improve. Catalyst-cured epoxies tend to blush if rain or dew deposit on the surface before partial curing takes place. This type blushing is not detrimental to the film and can be removed by wiping the surface with a rag saturated with epoxy thinner.

Failure to dry

a. Use of wrong or incompatible thinner in the paint.

b. Use of unclean equipment (such as brushes which have been stored in diesel oil).

c. Failure to add catalyst to catalyzed epoxy or phenolic coatings.

d. Use of paint which is too old. This is particularly true of blacks and dark greens.

e. Application of excessively thick coats.

Mildew

This is a black fungus growth which attacks the drying oil component of paints. It occurs only in areas of high humidity to paints of high oil content. It can be distinguished from dirt by the application of a few drops of a chlorine bleach, such as Clorox, to the surface.

Mildew will be bleached out in a short time, whereas dirt will not be bleached. Mildew is particularly noticeable on tank whites and white house paints. Before mildewed surface is repainted, it should be scrubbed thoroughly with a solution of chlorine bleach or trisodium phosphate, then it should be repainted with a mildew-resistant paint. Mildew preventives can also be added to the paint in the field. Most of these are mercury compounds; they can be purchased at most paint stores and hardware stores, or the paint manufacturer can be requested to include the mildewicide in the paint.

Darkening

This is caused by the action of sulfides in the air on lead pigments in the paint, and it will usually be fairly uniform over the entire surface. Light colored paints for use in sour crude fields should be made from non-lead pigments. Such paints are usually called "fumeproof."

Lapping

When each brush stroke or spray gun pass is visible after the paint has dried, the paint is said to show laps. This usually occurs when paints containing fast solvents are applied to hot steel in the summer. It is most noticeable with aluminum-pigmented paints on tanks, where the paint dries before the aluminum particles have had a chance to orient themselves in the paint film. The addition of a small amount of slow solvent, or retarder, usually cures this problem.

Miscellaneous Remedies for Some Oil Field Problems

There are several products in use in the oil field which, while not protective coatings in the strictest sense, are of sufficient interest to be included in this report.

Tank Sealing Compounds

These are usually catalyst-cured epoxy-thiokol mixtures. They are being used successfully for sealing the leaking seams of bolted or riveted tanks containing either crude or products. The tank is drained to below the level of the leak, the seam is cleaned thoroughly, and the sealing compound is applied by brush to a thickness of from 20 to 50 mils on the outside of the tank and around any rivets which are leaking. When the compound has cured, it may be painted over to match the rest of the tank. The polysulfide component gives the compound sufficient flexibility to resist the expansion and contraction of the seams.

Patching Compounds

These are catalyst-cured low molecular weight epoxy or polyester materials containing 100 percent solids by volume. As they cure there is no solvent evaporation, therefore no shrinkage. They come in two forms: (a) putty, in which the resin has been loaded with powdered metal (such as aluminum or iron) or with chopped glass fiber, and (b) the liquid resin.

In patching a hole, the tank or line is drained, the area around the hole is

cleaned, and a button of the putty is squeezed into the hole, allowing some of the putty to lap over onto the surrounding area. Holes have been repaired while the equipment is in service by driving a wooden plug into the hole, cutting the plug off flush with the surface, and applying the putty over the plug. A patch of glass fiber cloth is then saturated with the liquid and applied over the puttied area. In the case of pipe, several layers of the resin-saturated cloth are wrapped around the repaired area.

The resin-saturated cloth has been also used successfully for jacketing the legs of offshore platforms in the splash zone and for armoring the exterior of sections of tubing which are to be placed opposite the perforations on multiple-completed wells. The liquid resin itself is used as a thread dope where two threaded members are to be joined permanently, such as in casing strings.

Plastic tapes

These tapes, usually made of vinyl, polyethylene or butyl rubber modifications, are widely used for wrapping underground flow lines or water flood lines which pass through corrosive areas such as those near salt water pits or cooling towers. Most tapes have pressure sensitive adhesive already on them, but on at least one type, the adhesive is applied in the field. The tapes provide excellent hot-spot protection and can be applied with a minimum of labor. There is a great variation in the adhesive strength of the tapes and bonding strength to both the metal surface and to itself. If the line to be wrapped passes through oily soil, use only tapes with adhesives that have been checked for oil resistance.

Designing Against Corrosion

Of the 6 to 8 billion dollars which corrosion costs American industry each year, approximately 38 percent is spent for painting. This could be reduced considerably if proper attention would be paid to certain basic principles when equipment is being designed. In petroleum production, the golden days are over, and anything which will make for lower lifting costs should certainly be considered.

Since paint maintenance costs are calculated on the basis of x cents per square foot of surface area, the most obvious thing to do is to decrease the number of square feet to be maintained. This can be accomplished by substituting tubular members with sealed ends for the usual structural shapes such as angles, T's and I-beams when designing a piece of equipment.

The worst possible situation for painting is where angles or channels are placed back-to-back and skip-welded or placed slightly apart. It is impossible to clean and paint the foul or inaccessible areas of such members, corrosion cannot be controlled, and in time the members will deteriorate to the point where replacement is necessary. This can be avoided on the drawing board when the equipment is designed. By substituting hollow sealed tubes for such members, the surface area is substantially decreased, and

in addition, one-half of the surface area is removed from influence completely.

There are other factors which also contribute materially to maintenance painting costs. These are sharp edges or projections, crevices, shielded areas and soilage pockets. Almost without exception coating failures will occur first at one of those points, and once the film is broken the failure will spread to the plane surfaces. The reason may be found by a brief review of the fundamentals of paint technology. When applied, paint will form a film which, when it dries or cures, will tend to literally stretch over edges, projections, etc. This inherent property results in a finished film thickness on edges which is only a fraction as thick as the film on the flat surfaces. To prove this, try painting the point of a needle or the edge of a razor blade. It is known that up to a point, the life of a paint system is proportional to the coating thickness; thus the reason for early failure of edges and projections.

Crevices and shielded areas fail because no coating can be applied in the first place, and even though the unpainted area is sealed off by a paint film, no film is completely impervious to water vapor. Thus there exists a point of early coating failure.

Soilage pockets are also very undesirable in that they will hold water from rain, condensation, or wash-down. For a coating to hold up under these conditions, it must be suitable for immersion, and in almost every instance, an otherwise good atmospheric coating will fail.

From the foregoing it is possible to draw a few fundamental principles which can be applied in any design work, no matter how small or large the project:

1. Hold to a minimum the surfaces which will be exposed to corrosion. This can be accomplished by employing structural shapes of equal design characteristics but lesser exposed area per lineal foot, and by removing as much surface as possible from corrosive influence by seal-welding.
2. Avoid foul or inaccessible areas where it is impossible to prepare and paint the entire surface.
3. Avoid shielded areas such as lapped plates welded only on one side. Always specify complete seal welding.
4. Hold sharp edges, projections, etc. to a minimum.
5. Provide complete drainage from every part of the structure either by design or by drilling drainage holes in the members.
6. Cut stud bolts off so they lack approximately 1/16 inch of coming out to the flat exposed face of the nuts. Screw threads are very difficult to keep painted.
7. Specify that all welds will be ground down and that all weld spatter be removed before priming.

Safety Suggestions

Where fire or explosion hazards exist, proper precautions should be taken be-

fore any sandblasting, power tool cleaning, or solvent cleaning is performed. If the surface, container, or vessel being prepared for coating has previously contained or been exposed to flammable substances, it should be purged or cleaned of all concentrations of such substances before surface preparation starts.

When doing solvent cleaning or applying surface pretreatments or coatings in a confined space, adequate ventilation should be provided to keep the atmosphere below 20 percent of the lower explosive limit. Air moving equipment, spray equipment, and sandblast hose should be grounded to dissipate static charges. When solvent, pretreatment, or coating is applied, no source of ignition should exist in the immediate area. Workmen who apply these materials should wear clothing which will not generate a mechanical or static spark.

All sources of ignition such as fire, internal combustion engines with spark ignition systems, lighting systems, and persons smoking should be kept at least 150 feet away and preferably upwind from compartment openings during coating and drying operations. Sources of ignition should be kept at least 150 feet away from open containers of paint and solvents.

Waste or spilled materials should be disposed of in such a manner that they will not be likely to cause future property damage or bodily injury.

Summary

Protective coatings are "tools" which can be used in the control of corrosion of producing equipment. If used intelligently and properly, they will do a satisfactory job of separating a metal from a corrosive environment. No coatings last forever, and there are no cure-alls or miracle products, so beware of gimmicks. No coating will work just as well over rust as it will over properly prepared surface, regardless of what the high-powered full-color advertising literature might say.

Remember the following items:

- (1) Prepare the surface properly.
- (2) Choose the correct type coating for the intended service, and apply it according to the manufacturer's recommendations.
- (3) If the job is contracted out: (a) Choose a reputable contractor, not merely one who bids lowest; (b) Write adequate and firm specifications, particularly as to film thickness. "If you don't specify it, you don't get it."; (c) Have competent inspection of the job.
- (4) Schedule work to prevent coating damage: When welding above a painted surface, cover the surface with sand, dirt, sacks or anything that will prevent the weld spatter from dropping down and burning holes through the coating.
- (5) Do not overthin the paint. A gallon of paint plus a gallon of thinner does not make two gallons of paint.
- (6) Cheap paint and cheap painting are no bargains.

(7) Paint is a perishable commodity. Buy fresh paint, and buy only enough ahead for not more than a few months needs. The paint suppliers are not going to run out of paint.

(8) If difficulties are encountered with application, or if a coating does not perform as expected, call the paint manufacturer. Most manufacturers will send a competent field representative to the job to help iron out the difficulties.

The members of Technical Unit Committee T-6E hope that the compilation of information contained in this report will assist the users in getting more for their money in the way of protecting their petroleum production equipment through the use of protective coatings.

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APPENDIX

Sample Specification—SPECIFICATIONS FOR TANK PAINTING (Tank White System)

1. Scope

1.1 Paint applicator shall furnish all labor, material, and equipment to sandblast and paint the tanks in accordance with the following schedule.

2. Surface Preparation

2.1 All surfaces to be coated shall be sandblasted to a good grade commercial finish. This is defined as a surface from which all dirt, rust, old paint, and mill scale have been removed but which may still have shadows.

2.2 Blasting shall be done with 16 x 35 mesh silica sand and the abrasive shall be discharged from the nozzle at from 80 to 100 pounds pressure at the nozzle.

2.3 Blasting sand shall be cleaned, dry, and free of clay particles and other extraneous matter. Sand must be approved by owner's representative before any blasting is begun.

2.4 The compressed air used for blasting shall be free of detrimental amounts of water and oil. Adequate traps and separators shall be provided at the compressor.

3. Application

3.1 Paint application shall be done in accordance with paint manufacturer's recommendations and will be subject to inspection of owner's representative at all times.

3.2 All spray equipment shall be inspected and approved by owner's representative before any application is begun.

3.3 A moisture trap shall be placed in line from air supply to pressure pot and spray gun. This trap shall be opened slightly to provide a continuous bleed.

3.4 Regulators and gauges shall be provided for air to both pressure pot and spray gun.

3.5 All sand and dust from blasting operations shall be removed from surfaces before paint application is begun.

3.6 Blasted surfaces shall be coated with one coat of primer during the same day that blasting was done.

3.7 Primer shall not be applied closer than 6 inches to a non-blasted area.

3.8 No painting shall take place when the atmospheric temperature is below 40 F or when the surface temperature is below the dew point.

3.9 It is suggested that spray guns be held 6 to 8 inches from, and perpendicular to, the surface to be painted.

3.10 The sequence to be followed in painting shall be such that a minimum of damage to finished coatings will result.

3.11 Paint manufacturer or owner's representative will be consulted concerning points not covered herein.

4. Paint System

4.1 Apply by spray, brush, or roller, one coat inhibitive primer at a wet film

thickness of not less than 4 mils. This thickness can be obtained when the spreading rate over sandblasted surfaces is not greater than 350 sq. ft. per gallon, and will result in a dry film thickness of 1.5 mils. This spreading rate does

not take into consideration spraying losses.

4.2-Apply by spray, brush, or roller, one coat * intermediate coat brown at a wet film thickness of not less than 3 mils. This thickness can be ob-

* Company name goes here

tained when the spreading rate (not counting spraying losses) is not greater than 375 sq. ft. per gallon, and will result in a dry film thickness of not less than 1.5 mils.

4.3 Apply by spray one coat tank white at a wet film thickness of not less than 3 mils. This thickness can be obtained when the spreading rate (not counting spraying losses) is not greater than 400 sq. ft. per gallon and will result in a dry film thickness of not less than 1.5 mils. This coat may be tinted slightly with blue enamel, not more than

APPENDIX TABLE 1—Surface Areas of Various Sizes of Tanks

Tank Capacity, 43 Gal. Bbls.	Tank Diameter	Tank Height, Ft.	Square Foot Area of Roof	Square Foot Area of Shell	Total Square Footage*
500	15'	18	177	848	1,034
1,000	20'	18	314	1,131	1,461
1,500	25'	18	491	1,414	1,929
2,000	25'	24	491	1,855	2,400
2,500	25'	30	491	2,356	2,871
3,000	25'	36	491	2,827	3,342
3,750	30'	30	707	2,827	3,569
5,000	30'	40	707	3,770	4,512
5,000	35'	30	962	3,302	4,312
7,500	36'8"	40	1,064	4,608	5,725
7,500	40'	34	1,257	4,273	5,592
10,000	42'6"	40	1,425	5,341	6,838
10,000	45'	36	1,590	5,089	6,759
12,500	48'	40	1,810	6,032	7,932
15,000	48'	48	1,810	7,238	9,138
15,000	52'	40	2,124	6,535	8,765
20,000	60'	40	2,827	7,540	10,509
24,000	60'	48	2,827	9,048	12,017
25,000	67'	48	3,526	8,419	12,121
30,000	67'	48	3,526	10,103	13,804
30,000	73'4"	40	4,231	9,215	13,658
35,000	80'	40	5,026	10,053	15,331
42,500	80'	48	5,026	12,064	17,342
45,000	90'	40	6,362	11,310	17,990
54,000	90'	48	6,362	13,572	20,252
55,000	100'	40	7,854	12,566	20,813
67,000	100'	48	7,854	15,080	23,327
80,000	110'	48	9,503	16,588	26,567
80,000	120'	40	11,310	15,080	26,956
96,000	120'	48	11,310	18,096	29,972
100,000	134'	40	14,103	16,839	31,647
109,500	140'	40	15,394	17,593	33,757
120,000	134'	48	14,103	20,207	35,015
125,000	150'	40	17,672	18,850	37,406
131,500	140'	48	15,394	21,111	37,275
142,500	160'	40	20,106	20,106	41,217
150,000	150'	48	17,672	22,620	41,176
171,500	160'	48	20,106	24,128	45,239
180,000	180'	40	25,447	22,620	49,339
217,000	180'	48	25,447	27,144	53,863
224,000	200'	40	31,416	25,133	58,120
268,000	200'	48	31,416	30,159	63,146

* Total square footage includes 5 percent additional on roof area to allow for slope of conical roofs.
For estimating structural steel (per coat): Light steel (such as 2 x 2 angles): 1 to 1.1 gal per ton; medium steel: $\frac{3}{4}$ gal per ton; heavy steel: $\frac{1}{2}$ gal per ton.

APPENDIX TABLE 2—Surface Areas of Various Sizes of Pipe

Nominal Pipe Size In Inches	Outside Diameter In Inches	Pipe Surface Area In Square Feet Per 1000 Linear Feet
$\frac{1}{4}$	0.840	220
$\frac{3}{4}$	1.050	275
1	1.315	345
$1\frac{1}{2}$	1.900	498
2	2.375	623
3	3.500	920
4	4.500	1180
5	5.563	1456
6	6.625	1735
8	8.625	2260
10	10.75	2814
12	12.75	3339
*14	14.0	3667
16	16.0	4190
18	18.0	4714
20	20.0	5237
22	22.0	5761
24	24.0	6284
26	26.0	6801
28	28.0	7331
30	30.0	7900

* Pipe sizes of 14 inches and over are expressed in outside diameter.

Note: Listed above are exterior surface areas of different sizes of steel piping used in petroleum refineries and other processing industries. This table will serve as a guide in estimating the number of gallons of paint required for various diameters and lengths of pipe.

APPENDIX TABLE 3—Dry Film Thicknesses* Obtainable as Related to Solids Content and Spreading Rate

Film Forming Solids by Volume, Percent	Coverage Rates, Sq. Ft. Per Gallon																					
	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	
10.....	1.6	1.3	1.1	.9	.8	.7	.6	.6	.4													
15.....	2.4	1.9	1.6	1.4	1.2	1.1	1.	.9	.8	.7	.7	.6	.6	.6	.5							
20.....	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.2	1.1	1.	.9	.8	.8	.8	.7	.7	.6	.6	.6	.6	.5	
25.....	4.	3.2	2.7	2.3	2.	1.8	1.6	1.5	1.4	1.2	1.1	1.1	1.	1.	.9	.8	.8	.8	.7	.7	.7	
30.....	4.8	3.8	3.2	2.7	2.4	2.1	1.9	1.8	1.6	1.5	1.4	1.3	1.2	1.1	1.1	1.	1.	.9	.8	.8	.8	
35.....	5.6	4.5	3.7	3.2	2.8	2.5	2.2	2.1	1.9	1.7	1.6	1.5	1.4	1.3	1.2	1.1	1.1	1.1	1.	1.	.9	
40.....	6.2	5.1	4.3	3.6	3.2	2.8	2.6	2.4	2.2	2.	1.8	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.2	1.1	1.1	
45.....	7.2	5.8	4.8	4.1	3.6	3.2	2.9	2.7	2.4	2.2	2.	2.	1.8	1.7	1.6	1.5	1.4	1.4	1.3	1.3	1.2	
50.....	8.	6.4	5.4	4.6	4.	3.6	3.2	2.9	2.7	2.4	2.3	2.1	2.	1.9	1.8	1.7	1.6	1.5	1.5	1.4	1.4	
55.....	8.8	7.	5.9	5.	4.4	3.9	3.5	3.2	3.	2.7	2.5	2.3	2.2	2.1	1.9	1.8	1.8	1.7	1.6	1.5	1.5	
60.....	9.6	7.7	6.4	5.5	4.8	4.3	3.8	3.5	3.2	2.9	2.7	2.5	2.4	2.3	2.1	2.	1.9	1.8	1.7	1.7	1.6	
65.....	10.4	8.3	7.	5.9	5.2	4.6	4.2	3.8	3.5	3.2	2.9	2.7	2.6	2.5	2.3	2.1	2.1	2.	1.9	1.8	1.8	
70.....	11.2	9.	7.5	6.4	5.6	5.	4.5	4.1	3.8	3.4	3.2	2.9	2.8	2.7	2.5	2.3	2.2	2.1	2.	2.	1.8	
75.....	12.	9.5	8.	6.8	6.	5.1	4.8	4.4	4.	3.7	3.4	3.2	3.	2.9	2.6	2.5	2.4	2.3	2.2	2.1	2.	
80.....	12.8	10.	8.6	7.3	6.4	5.7	5.1	4.7	4.3	3.9	3.6	3.4	3.2	3.	2.8	2.6	2.6	2.4	2.3	2.2	2.2	
85.....	13.6	10.7	9.2	7.7	6.8	6.	5.4	5.	4.6	4.2	3.8	3.6	3.4	3.4	3.	2.8	2.7	2.6	2.5	2.3	2.3	
90.....	14.4	11.5	9.6	8.2	7.2	6.4	5.8	5.3	4.9	4.4	4.1	3.8	3.6	3.4	3.2	3.	2.9	2.7	2.6	2.5	2.4	
95.....	15.2	12.2	10.2	8.7	7.6	6.8	6.1	5.5	5.1	4.7	4.4	4.1	3.8	3.6	3.4	3.2	3.	2.9	2.8	2.7	2.5	
100.....	16.	12.8	10.7	9.2	8.	7.1	6.4	5.8	5.4	4.9	4.6	4.3	4.	3.8	3.6	3.4	3.2	3.1	2.9	2.8	2.7	

* In Mils.

½ ounce per gallon, to provide a color break, if desired.

4.4 Apply by spray final coat tank white at a wet film thickness of not less than 3 mils. This will result in a dry film thickness of not less than 1.5 mils.

4.5 Total dry film thickness after 5 days drying time shall not be less than 6 mils as measured by an Elcometer, Tinsley Gauge, or Mikrotest.

4.6 In the event that application of the tank white is to be done in an area where spraying is not permitted and application must be by brush or roller, * tank white should be used in place of * tank white. This is

* Company name goes here.

the same product with a different solvent balance.

4.7 All materials can be sprayed as received. In the event that under certain conditions thinning might be necessary * spraying thinner or mineral spirits thinner can be used. However, if the material is thinned, wet film thickness should be increased proportionately. On very hot steel in the summer, it may be necessary to add a small amount of * retarder thinner to give proper flowout for roller application.

5. Miscellaneous

5.1 After award of contract, the paint applicator shall contact the * paint company and submit a schedule of

paint requirements. It shall be the paint applicator's duty and responsibility to submit this schedule sufficiently in advance of work to insure delivery of adequate quantities of paints to meet job requirements.

5.2 Any deviation from these specifications without written permission from owner's representative shall be considered a breach of contract.

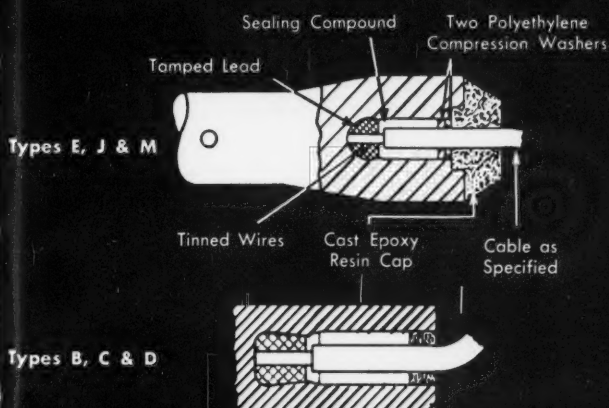
5.3 An inspection of the job will be conducted by representatives of paint applicator, paint manufacturer, and owner prior to final acceptance of the job. The paint applicator shall correct such work as is found defective under the specifications.

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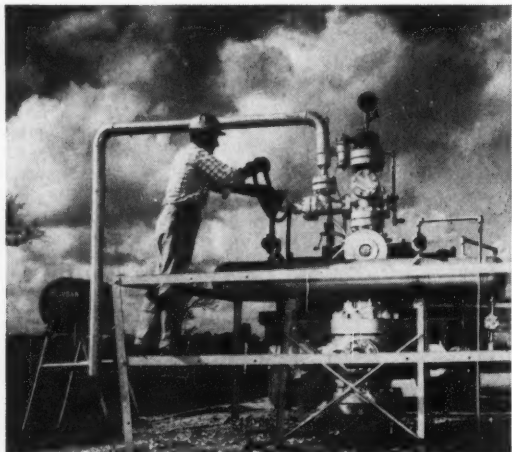


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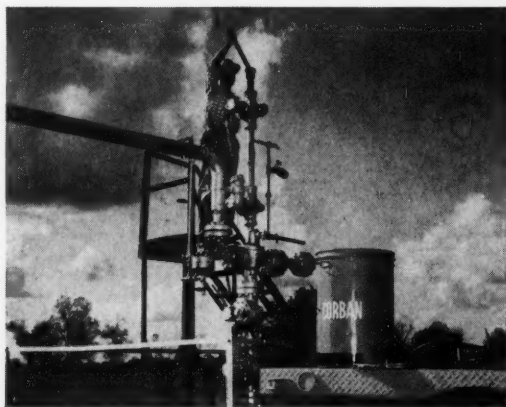
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